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EDN®

Industrial electronics product showcase

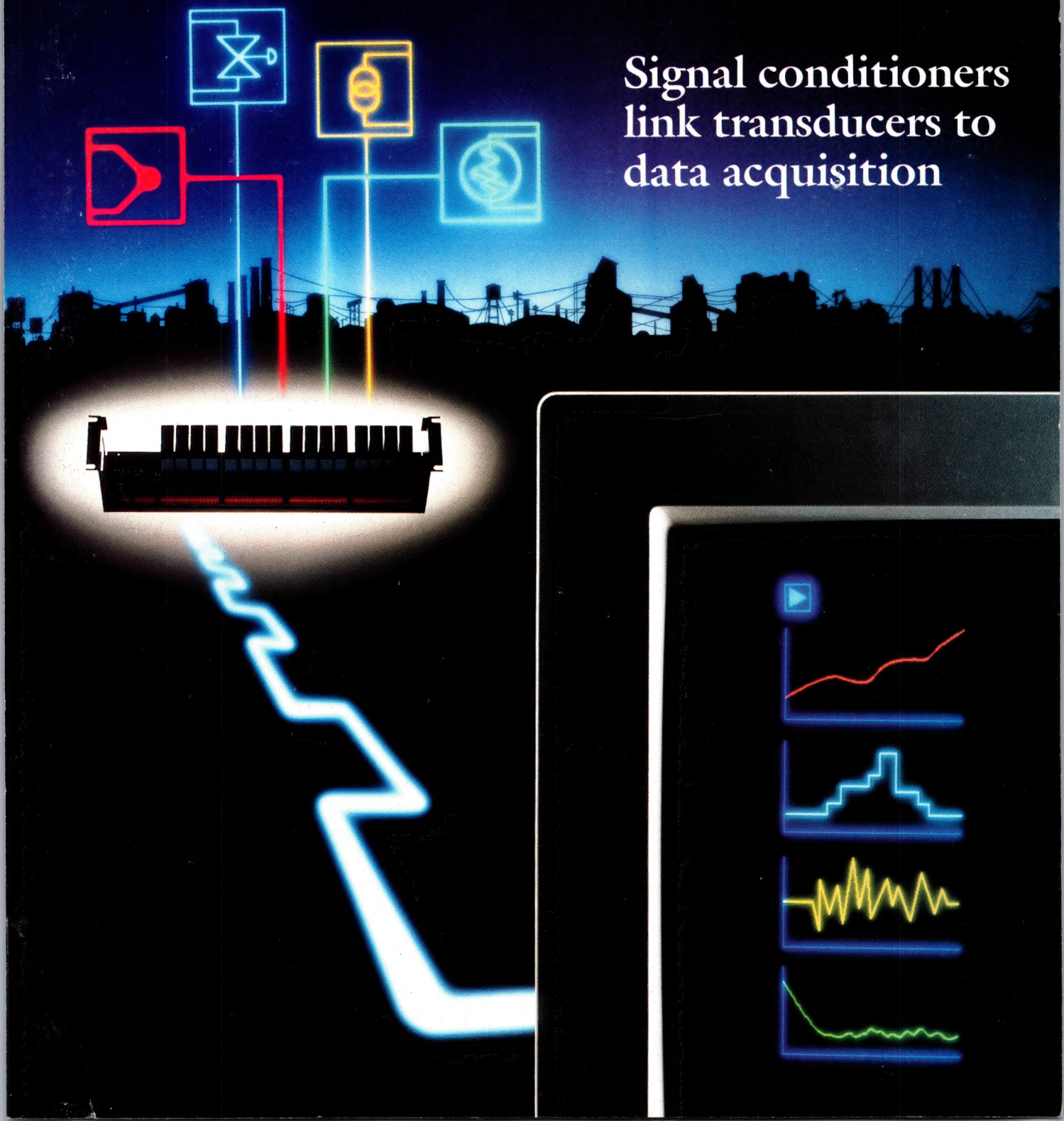
Troubleshooting analog circuits—Part 9

FDDI ICs and standardized components

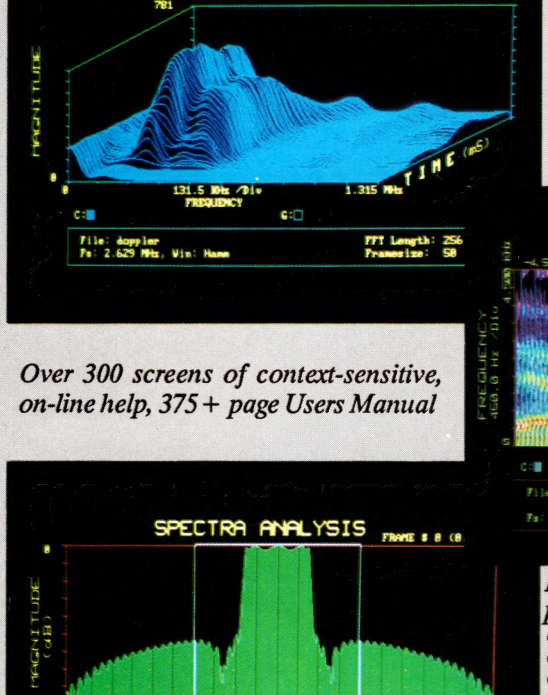
Motor-control ICs

ELECTRONIC TECHNOLOGY FOR ENGINEERS AND ENGINEERING MANAGERS

Signal conditioners link transducers to data acquisition



Display the beauty...



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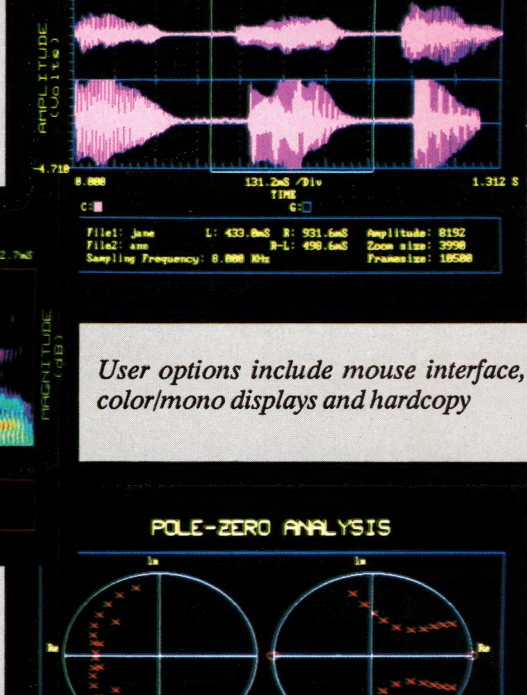

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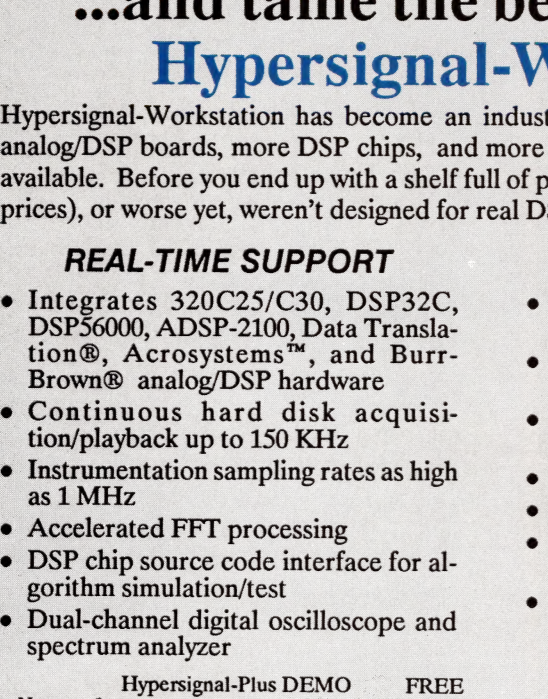

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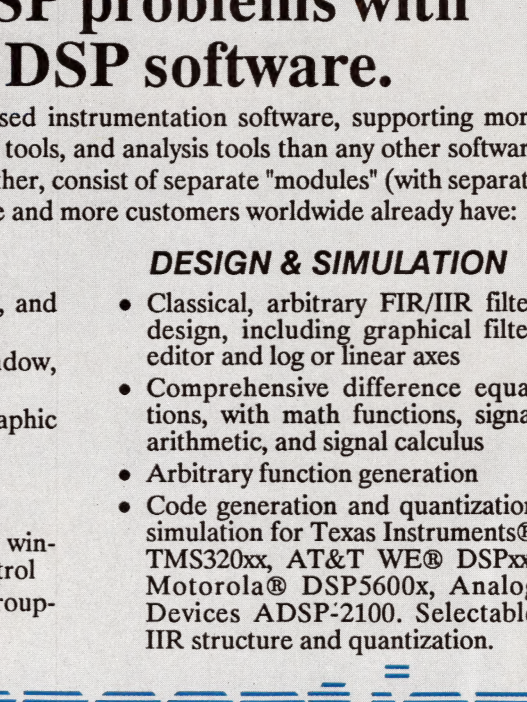
- *Burr-Brown®*
- *CAC (Communications, Automation, and Control)*
- *Data Translation®*
- *Motorola®*
- *Spectrum Signal Processing (Loughborough Sound Images)*
- *Texas Instruments®*



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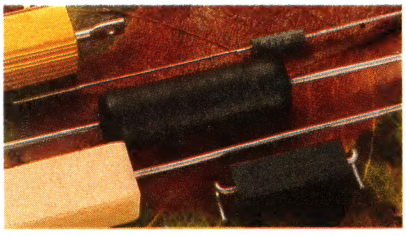

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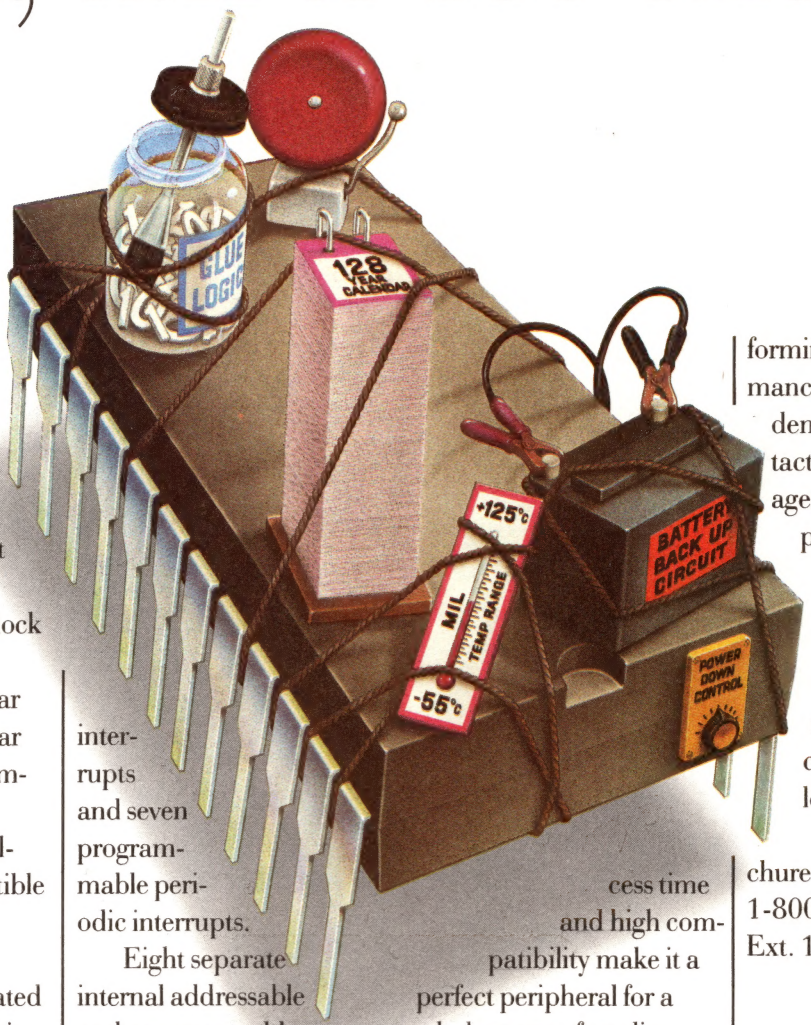

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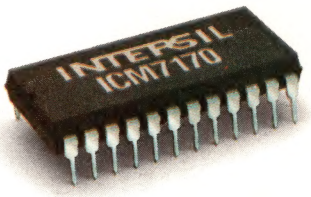

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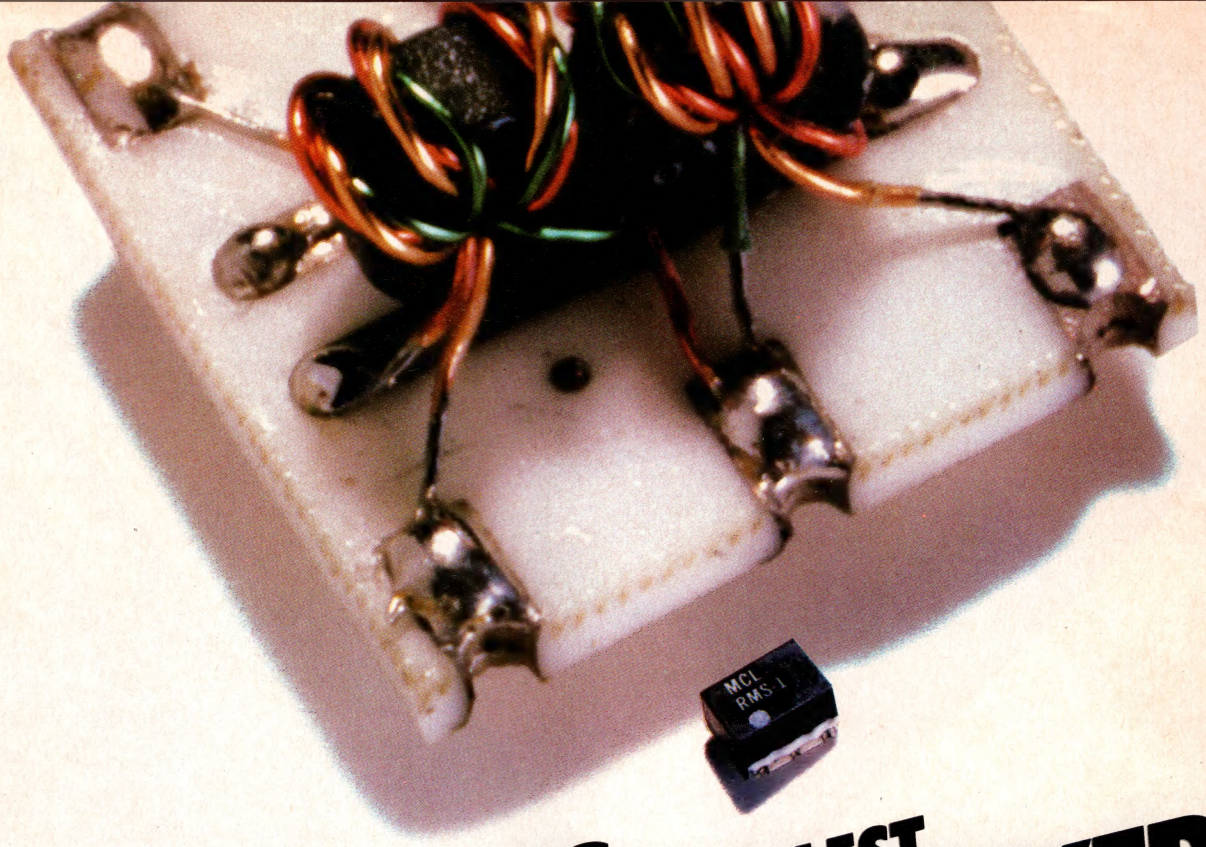

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RMS-1R	0.5-500	DC-500	+7	5.5	33	30	14.45
RMS-2	5-1000	DC-1000	+7	6.5	35	30	8.95
• RMS-2LH	5-1000	DC-1000	+10	6.5	35	30	10.45
• RMS-2MH	5-1000	DC-1000	+13	6.5	35	30	11.45
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September 14, 1989

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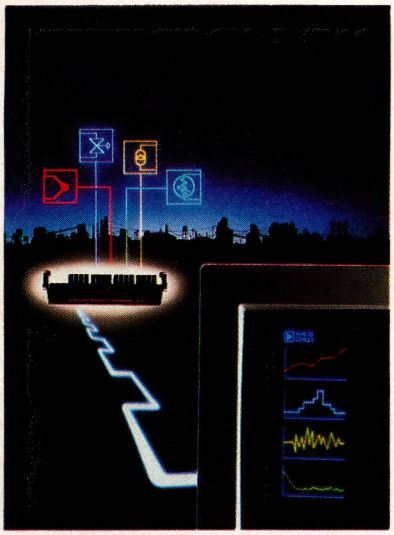

On the cover: *Signals from a thermocouple, a resistive sensor, and an ac source provide signal-conditioner inputs; a D/A converter drives a servo valve. A computer's color graphics display shows the conditioned signals. See pg 136. (Photo courtesy Analog Devices Inc)*

SPECIAL REPORT

DESIGN FEATURES

TECHNOLOGY UPDATES

Continued on page 7

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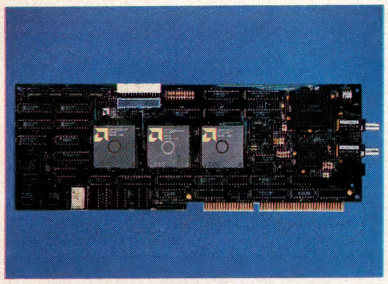

***New FDDI boards** and chip sets will hasten the acceptance of the 100M-bps network (pg 81).*

Continued on page 9

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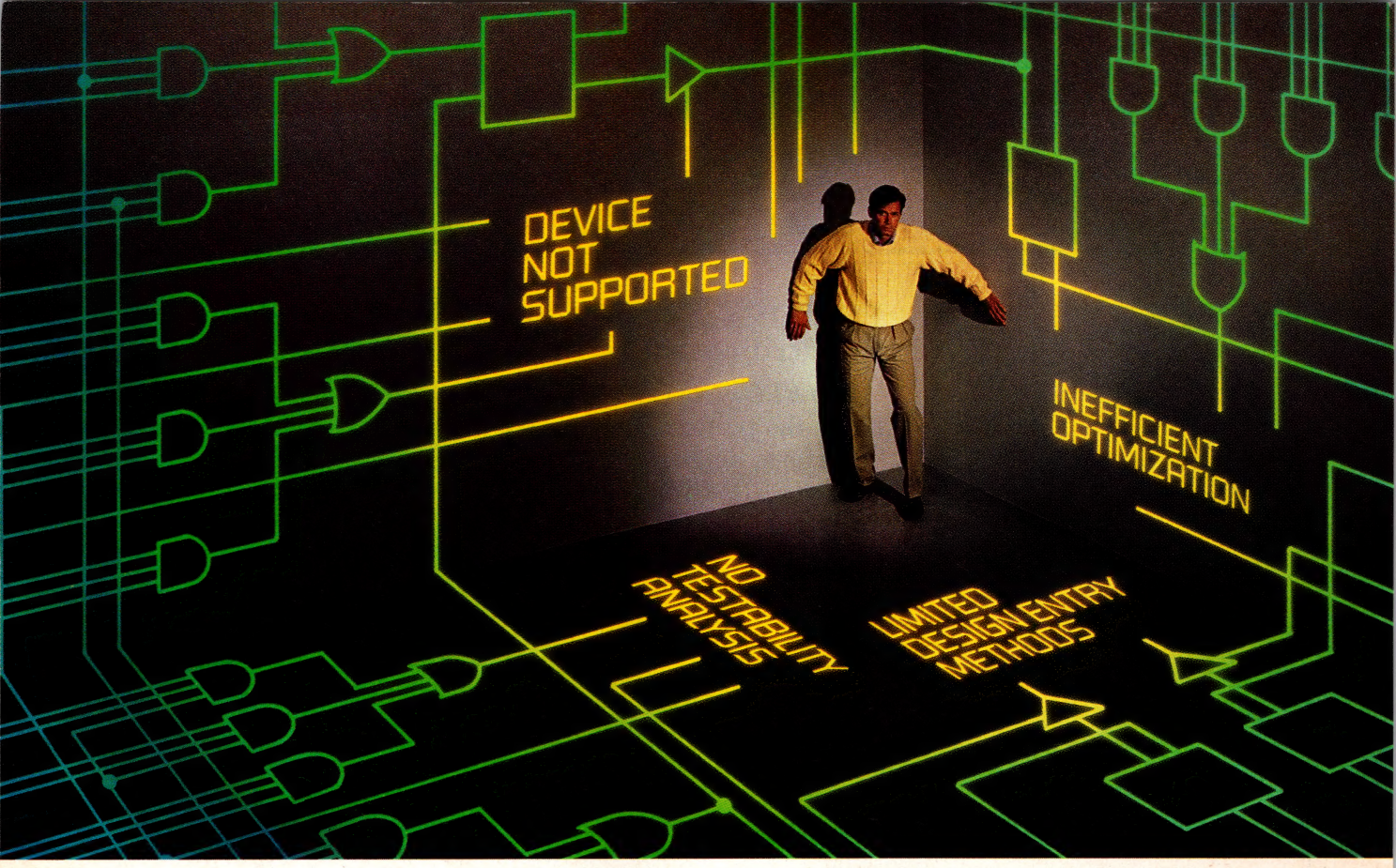

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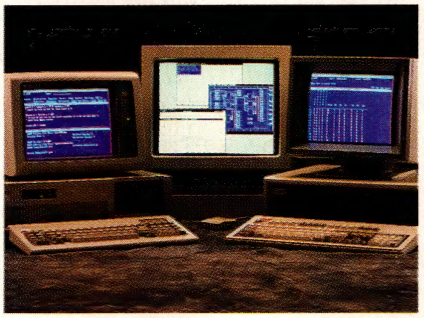

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EDITORIAL 51

Our editor tackles several topics, from engineering to global affairs.

NEW PRODUCTS

PROFESSIONAL ISSUES 241

Business ethics is not a contradiction in terms.
—Jay Fraser, Associate Editor

DEPARTMENTS


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	IMS 1203M	25,35,45
1K×4	IMS 1223	20,25,35,45
	IMS 1223M	25,35,45
16K×1	IMS 1403	25,35,45,55
	IMS 1403M	35,45,55
	IMS 1403LM	35,45,55
	IMS 1400M	45,55,70
	MK41H67	20,25,35
4K×4	IMS 1423	25,35,45,55
	IMS 1423M	35,45,55
	IMS 1420M	55,70
	MK41H68	20,25,35
	MK41H69	20,25,35
	MK41H79	25,35
2K×8	MK6116	150,200
2K×8	MK6116L	150,200
	MKI6116	150,200
	MKI6116L	150,200
64K×1	IMS 1600	20,30,35,45,55
	IMS 1601L	45,55
	IMS 1600M	45,55,70
	IMS1601LM	45,55,70
16K×4	IMS 1620	25,30,35,45,55
	IMS 1620M	45,55,70
	IMS 1620LM	45,55,70
	IMS 1624	25,30,35,45,55
	IMS 1624M	45,55,70
	IMS 1624LM	45,55,70
8K×8	**IMS 1630M**	**55,70**
	IMS 1630L	**45,55,70,100,120**
	MK48H64	**70,120**
	MK48H64L	**70,120**

Key: M – Mil-std-883C,L – Low Power. Available soon – a new 256K SRAM.

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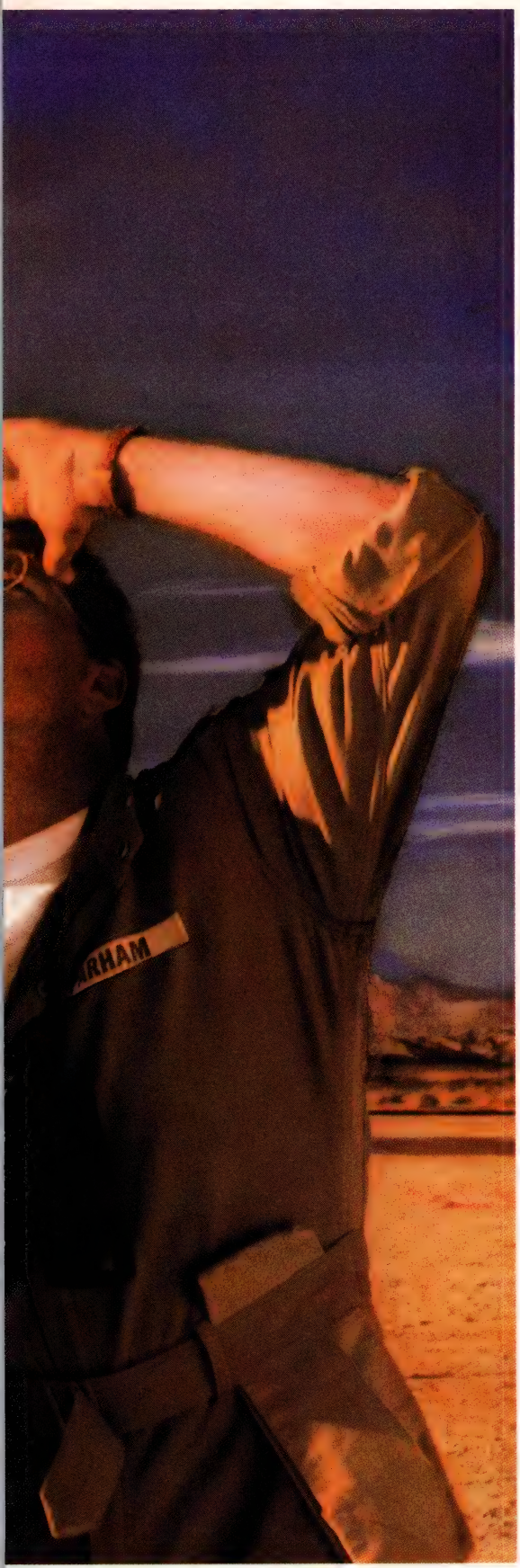
Who was the second person

Captain James Fitzgerald was the second person to break the sound barrier at Muroc Dry Lake, on February 24, 1948.

to break the sound barrier?



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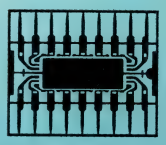

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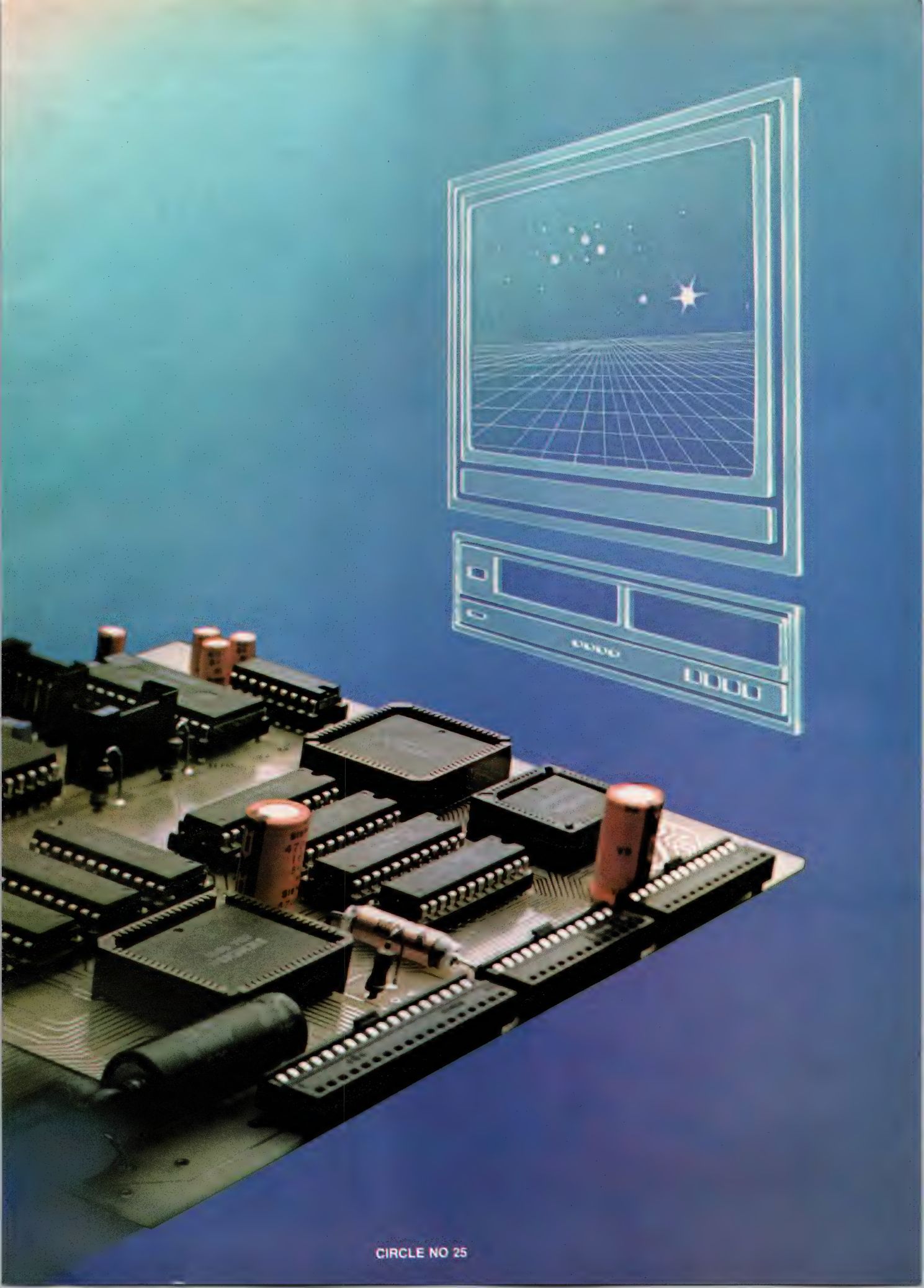

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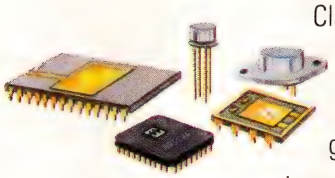

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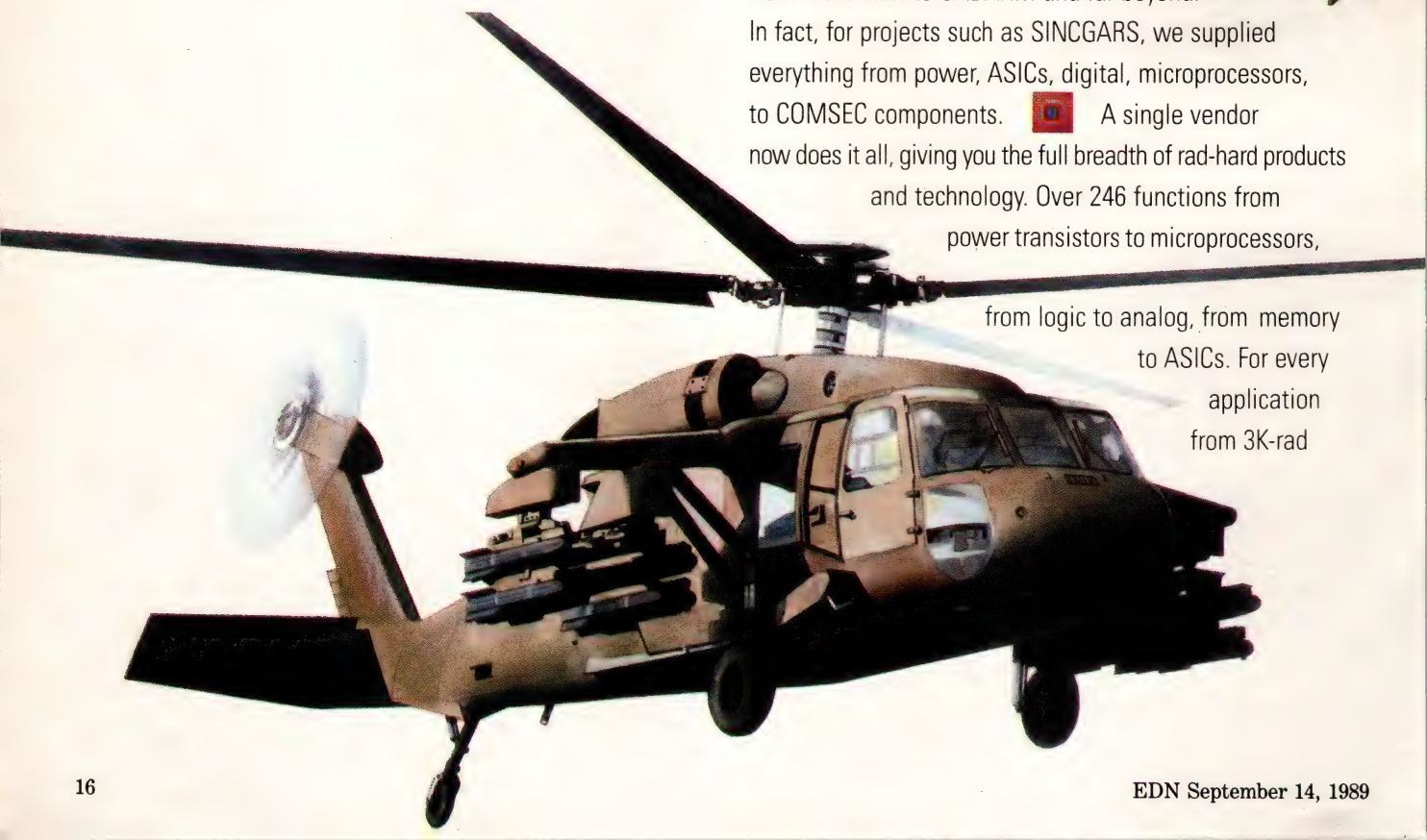

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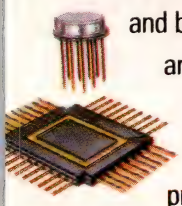

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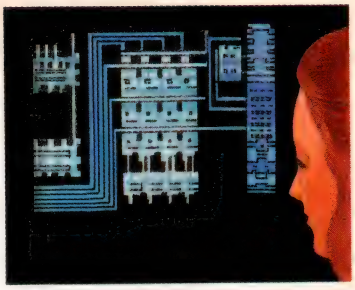

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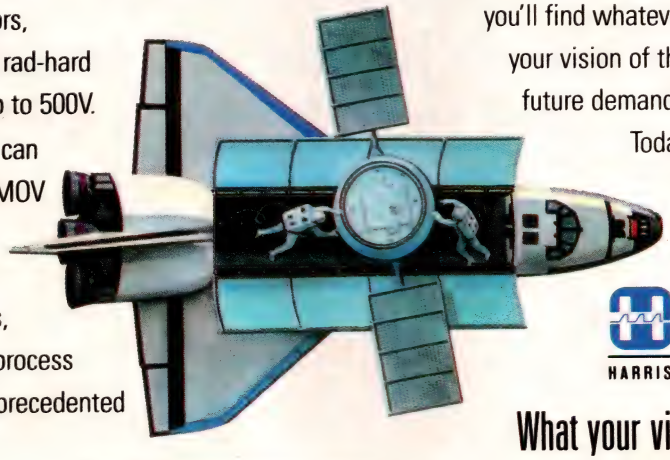

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CIRCLE NO 30

NEWS BREAKS

EDITED BY JULIE ANNE SCHOFIELD

DATA-ACQUISITION SYSTEM-ON-A-CARD CONSUMES 600 mW

The $595 SBS-2300, an intelligent data-acquisition board from Octagon Systems Corp (Westminster, CO, (303) 426-8540), draws only 600 mW yet provides a 12-bit A/D converter with an input multiplexer that accommodates eight single-ended or four differential inputs, two 12-bit analog output channels, 48 digital I/O lines, a keypad port, three programmable serial ports, an onboard EPROM and EEPROM programmer, 32k bytes of RAM, and a Hitachi HD64180 μP. The board also includes the company's CAMBASIC II programming language and development system. CAMBASIC II supports as many as 32 background tasks, including nine counters and eight timers, and the language has built-in functions for measuring frequencies and generating pulse trains. An optional networking module lets you create a data-acquisition network using as many as 32 SBS-2300s and an IBM PC or compatible computer.
—Steven H Leibson

HARDWARE-SIMULATOR PRICES FALL

IKOS Systems (Sunnyvale, CA, (408) 245-1900) has lowered the price of its IKOS 800 system, an entry-level hardware simulator. With a capacity for simulating about 20,000 gates, the IKOS 800 with a 16KS logic evaluator board costs $25,000—a decrease of more than 50%. For designs with as many as 80,000 gates, the IKOS 800 with a 64KS board costs $55,000—down almost 30%. The system is expandable to simulate designs larger than 1,000,000 gates.—Michael C Markowitz

MODEM ADDRESSES EUROPEAN APPLICATIONS

A K-series modem IC, the SSI 73K321L from Silicon Systems (Tustin, CA, (714) 731-7110), complies with both V.23 and V.21 protocols. The chip, which draws 30 mW from a 5V supply, provides 1200-bps operation for Videotex applications in V.23 mode and allows a 300-bps fallback for PC and other telecommunications applications in V.21 mode. The modem IC detects and generates the 2100-Hz answer tone for call initiation. Other chip functions include an FSK modulator/demodulator, call progress and handshake tone-monitor test modes, and a tone generator that can produce DTMF, answer, and calling tones. The IC is available in 22- and 28-pin DIPs as well as in a 20-pin plastic leaded chip carrier. Prices start at $11 (100).
—Michael C Markowitz

COMPANIES PROMISE INTERCHANGEABLE FDDI TRANSCEIVERS

In order to accelerate the use of Fiber Distributed Data Interface (FDDI) data networks, AT&T (Allentown, PA, (800) 372-2447), Hewlett-Packard (Palo Alto, CA, (800) 752-0900, ext 6447), and Siemens (Evansville, IN, (800) 827-3334) have agreed to develop optical transceivers that will be electrically and physically interchangeable. The three companies have established common specifications for pinout, package size, footprint, logic interface, and power requirements. The transceivers will also be fully compliant with the existing FDDI physical-media-dependent standard. Each company will independently develop and market its product. Samples of the transceivers will be available from each company in the fourth quarter of this year. The physical and electrical specifications are available now.—Richard A Quinnell

NEWS BREAKS

C DEVELOPMENT SYSTEM COMBINES OPTIMIZER AND DEBUGGER

Microtec Research's (Santa Clara, CA, (408) 980-1300) MRI C Development System for the Sun 3 comprises an ANSI C optimizing compiler, a Motorola-compatible 680XX macro assembler, and a source-level debugger. Because the compiler and the debugger are tightly coupled, you can write your code, run the optimizer, and debug the optimized code without ever having to leave the development system. The system's tools are compatible with the company's cross-development products, thus easing the migration of code between native and cross-development environments. The system costs $2800.—Margery Conner

RISC-BASED 66-MIPS μP INCLUDES DMA AND BUS CONTROLLERS

Offered at speeds as fast as 33 MHz, the i960CA from Intel (Santa Clara, CA, Dept LG42 (800) 548-4725) achieves a peak performance level of 66 MIPS (native instructions). The processor offers code compatibility with the 80960KA μP introduced last year, but it includes DMA, bus, and interrupt controllers that let you use the processor in embedded designs with a minimum of support chips. Key architectural features of the i960CA that result in the processor's ability to regularly execute two instructions per clock cycle include parallel instruction decoding; a 1k-byte, 2-way-set-associative instruction cache; multiple parallel-execution units; multiport register file with scoreboarding; and multiple internal buses.

You can also choose from a number of development tools offered for use with the i960CA. The tools include the iC960 optimizing C compiler and the ASM960 macro assembler, which cost $700 and $900, respectively, for MS-DOS-based personal computers. Samples of the i960CA are available now and production quantities should follow in the fourth quarter of this year. The μP comes packaged in a 168-pin PGA in 16-, 25-, and 33-MHz versions that cost $273, $303, and $379, respectively (1000). —Maury Wright

RISC-BASED 32-BIT VMEBUS CPU BOARD OFFERS 66 MIPS

If you need a high-performance CPU board for your VMEbus system, you can buy the HK80/V960E, which is based on Intel's 32-bit 960CA RISC chip, for $2795 (100). The 40-MHz Intel IC provides peak-performance specs of 66 native MIPS and 30 VAX MIPS, and includes a 1k-byte instruction cache, 1k byte of static data RAM, and a 4-channel, 32-bit DMA controller. The board is manufactured by Heurikon Corp (Madison, WI, (608) 251-8715) and uses a 2-way interleaved architecture to provide zero-wait-state memory access. It comes with 2M bytes of 70-nsec, dual-access, static-column RAM, which is expandable to 8M bytes. The HK80/V960E also contains 1M byte of EPROM and 128 bytes of nonvolatile RAM. The 33-MHz version of this board provides VMEbus transfer speeds reaching 40M bytes/sec. I/O capabilities include onboard SCSI and Ethernet interfaces. You also get a Unix cross-development program called VxWorks, which lets you develop your application on a Unix host, such as a Sun workstation, and then download the resulting code to an HK80/V9 60E. —J D Mosley

HIGH-END DSOs WITH HIGH-SPEED DSP: NOW IT'S A HORSERACE

With the introduction of its 7200 series, which is priced from $32,900, LeCroy Corp (Chestnut Ridge, NY, (800) 553-2769; FAX 914-425-8967) has turned the market for high-end digital storage oscilloscopes with built-in, high-speed digital signal processors into a horserace. For a few months, Tektronix (Beaverton, OR, (800)

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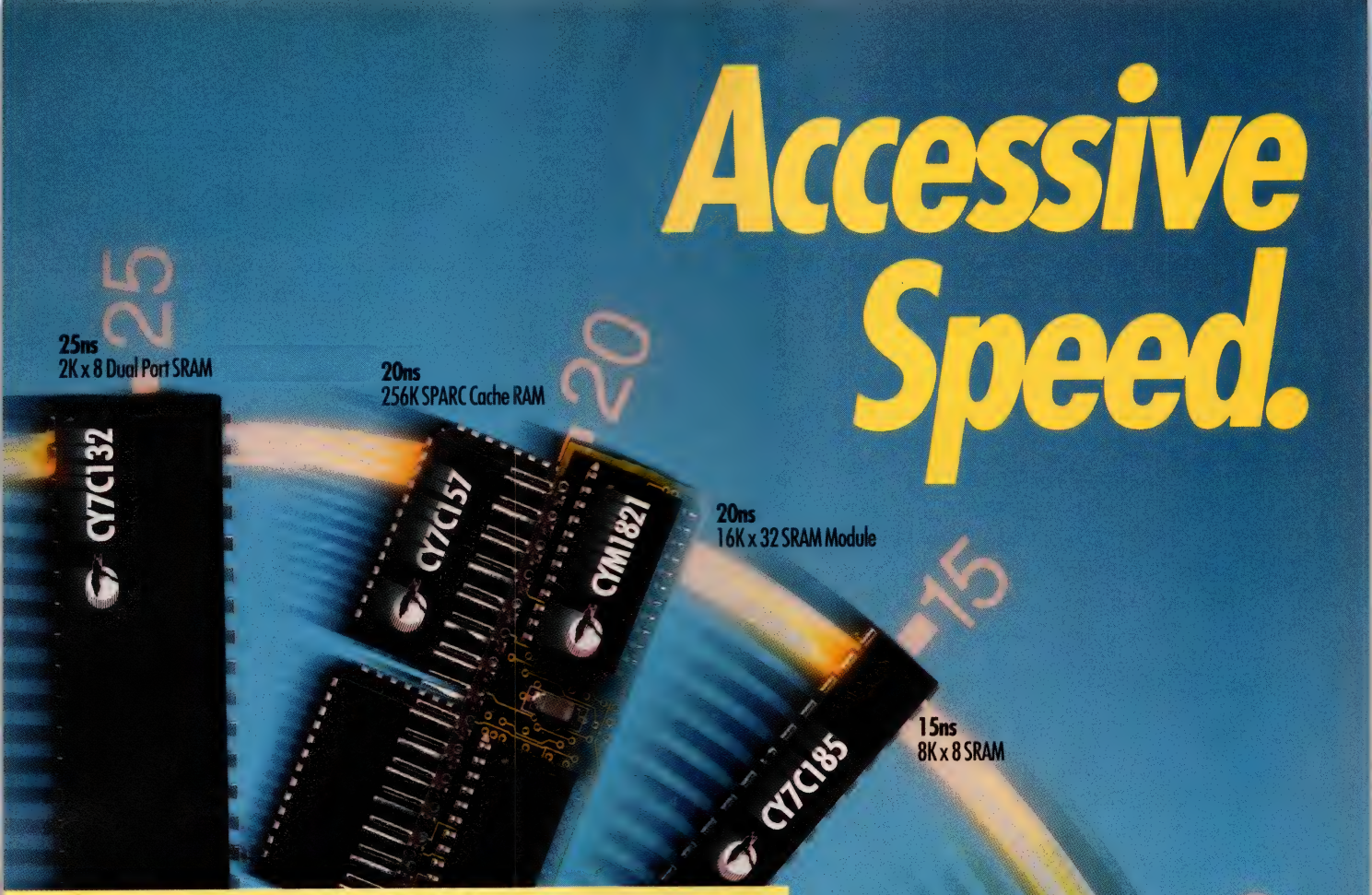

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835-9433) had this niche to itself with its DSA 600 series. Although the LeCroy product can't match Tektronix's 2G-sample/sec single-shot acquisition rate, which is obtained by using the 4-channel unit in single-channel mode, it can simultaneously take 1G samples/sec on four channels in real time—something the DSA units can't do.

For repetitive signals, the 7200 effectively takes 20G samples/sec; for single-shot and repetitive phenomena, its bandwidth is 400 MHz. At 50k samples/channel, the waveform-capture memory, which is unusually deep, allows the calculation of frequency spectra with very high resolution. In addition, the transform algorithm doesn't force a power-of-2 sample-set size. Word length is 8 bits and is extendible to 11 bits for repetitive signals by the use of DSP. Although the 7200 lacks a color CRT, it sports an amber monochrome display and a 3½-in. floppy-disk drive that writes waveforms and measurement-setup data onto MS-DOS-formatted disks. Also, the 7200's operator interface lets you "drive" the scope like an analog instr ument. —Dan Strassberg

REAL-TIME OS RUNS ON 80386 AND 68020/30/40 μPs

At this month's Buscon meeting, Microware Systems Corp (Des Moines, IA, (515) 224-1929) introduced a real-time operating system for high-performance, 32-bit μPs called OS-9000, which is upwardly compatible with the company's earlier OS-9 operating system. Versions of the new OS run on the Intel 80386 and Motorola 68020, 68030, and 68040 μPs; the company plans to offer versions for the Motorola 88000 and Intel 80486 μPs early in 1990. OS-9000 consists of a kernel, and I/O, file-management, utility, and development modules. The I/O, utility, and development modules and 95% of the kernel are written in C to promote portability of the OS across various μP architectures.

OS-9000 lets you add or delete modules dynamically to conserve memory in a host system and to create optimal configurations of the OS for specific applications. The OS also lets you choose either a priority-based, preemptive, multitasking scheduler or a time-shared, multiuser scheduler. In OEM quantities, the industrial version of OS-9000, which includes the kernel, interprocess communications, and console-I/O modules, costs $350. In similar quantities, Professional OS-9000, which includes the industrial version of the OS, more than 70 utility commands, and a C compiler, starts at $650.—Steven H Leibson

AFFORDABLE VXIBUS PRODUCTS AVAILABLE

The VXIbus is scarcely a year old, but most of the early product offerings from a dozen vendors gave VXI the aura of a system so expensive that it might only appeal to designers of military ground-support systems. These designers will pay dearly for hardware substantially smaller than rack-and-stack products that perform equivalent functions. But in one multiproduct announcement, Hewlett-Packard Co (Loveland, CO, (800) 752-0900) has gone a long way toward dispelling the VXI system's pricey image. Included in the long new-product list are 15 B-size modules carrying prices from $400 for a breadboard module to $2100 for an 18-GHz microwave switch. A B-size, 5½-digit multimeter costs $1200; a B-size mainframe costs $2300 with a blank front panel and $2800 with controls and a display. The C-size offerings include a $1600, 5½-digit multimeter and a $3500, 6½-digit multimeter. In addition to these two modules and five other C-size units, the vendor has announced a significant upgrade in the capabilities of its $6275 C-size mainframe.—Dan Strassberg

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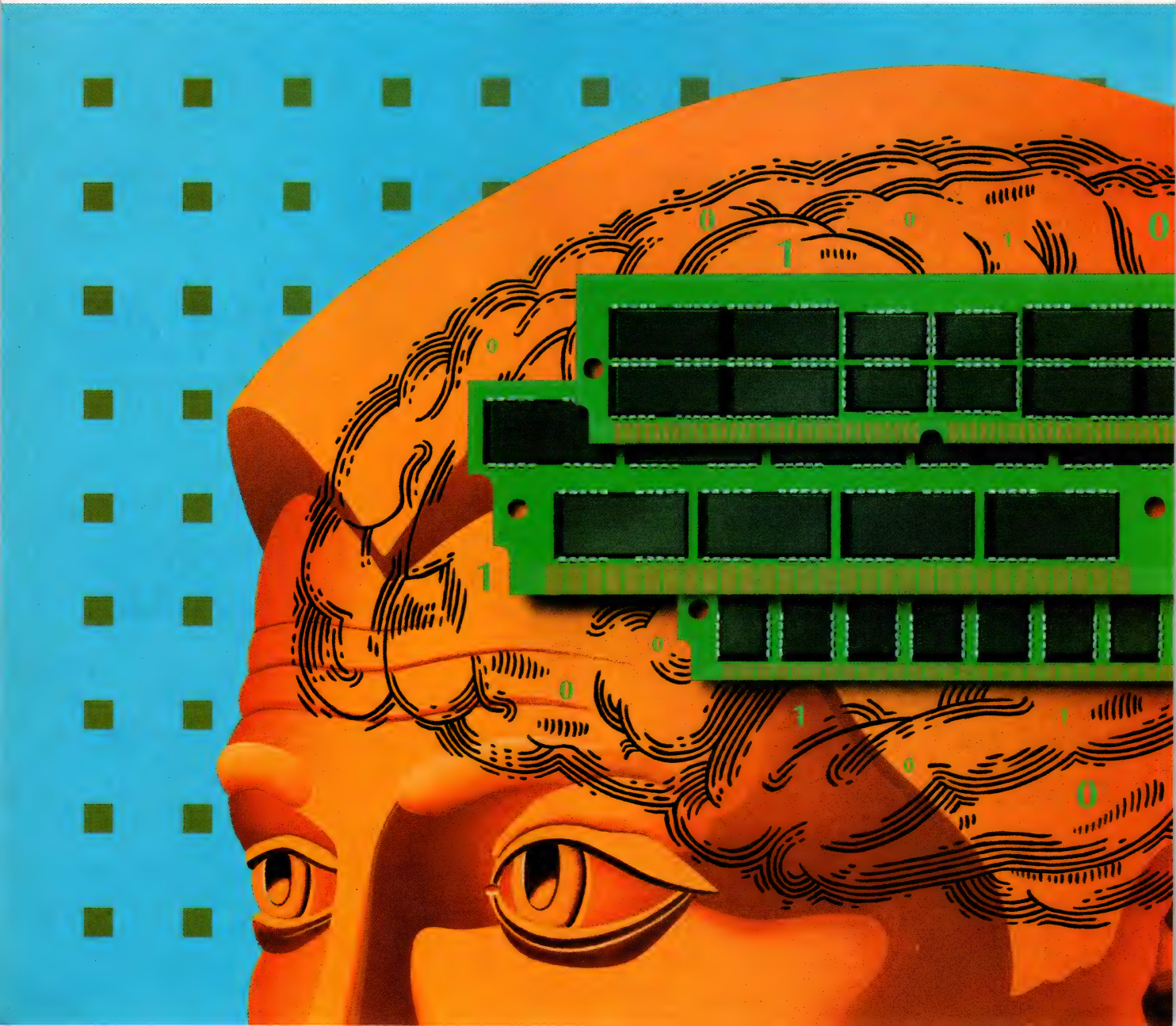

Speed. Low power consumption. Broad selection. Package and assembly expertise from one supplier. All essential memory ingredients for your next-generation designs. And they're all available from Oki Semiconductor. Our new-generation memory modules—built with the most advanced surface mount technology—have been designed with your future applications in mind.

We offer standard x8 and x9 SIMMs and JEDEC standard-dimension x36, x32, and x18s with customer specific pin-outs. No need to design your system around a standard part. Just specify the custom Oki SIMM that matches the design you have in mind. Our entire memory family is manufactured in an ultramodern, Class 1 facility, dedicated to supplying the industry's highest quality memory devices.

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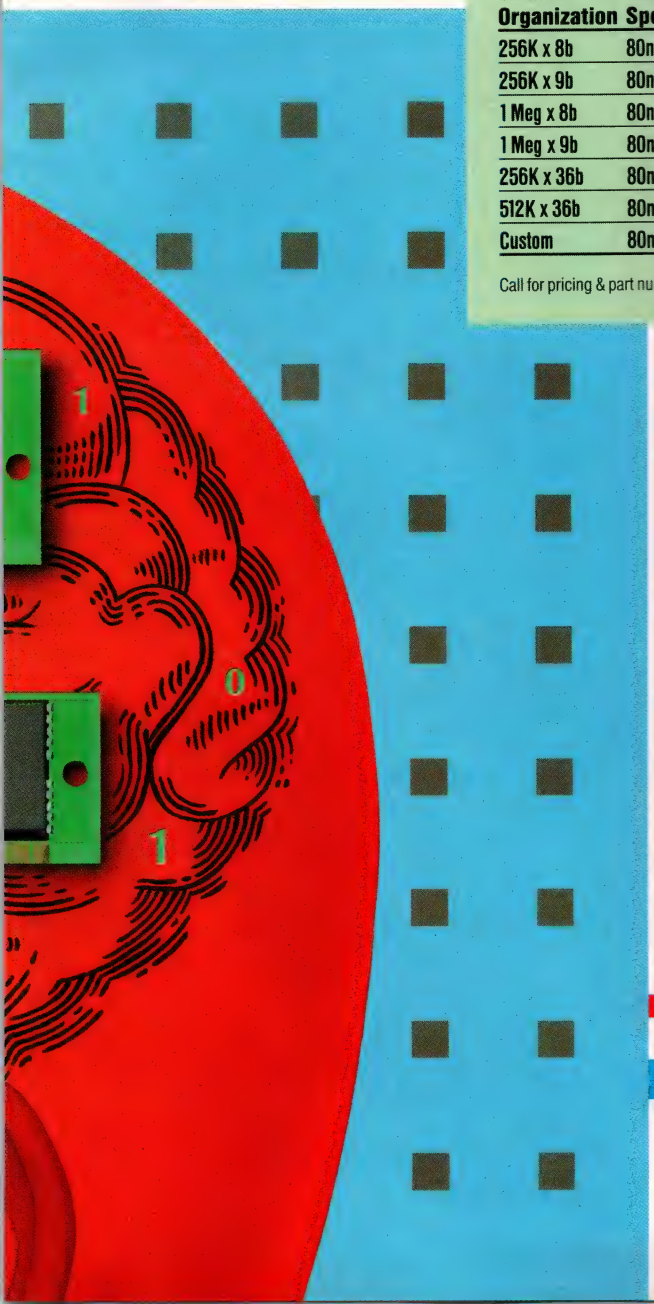
If you need high-performance features from a full-line memory family—Oki Semiconductor is your supplier. Call your local Oki field office today for more information on the next-generation memories you've been thinking about.

		Package	
Organization	**Speeds**	**Outline**	**Pinout**
256K x 8b	80ns, 100ns, 120ns	JEDEC	JEDEC
256K x 9b	80ns, 100ns, 120ns	JEDEC	JEDEC
1 Meg x 8b	80ns, 100ns, 120ns	JEDEC	JEDEC
1 Meg x 9b	80ns, 100ns, 120ns	JEDEC	JEDEC
256K x 36b	80ns, 100ns, 120ns	JEDEC	Custom
512K x 36b	80ns, 100ns, 120ns	JEDEC	Custom
Custom	80ns, 100ns, 120ns	Custom	Custom

Call for pricing & part numbers



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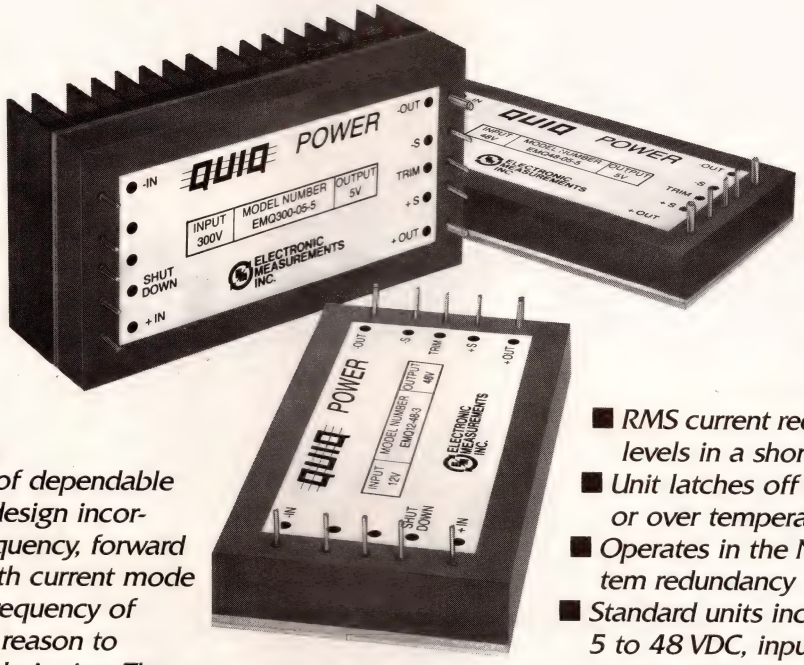
CIRCLE NO 35

The last thing you need from your DC/DC converter is a surprise!

The Magic Module™— the ultimate in proven performance, power capability, size and features...



When designing a DC/DC converter into your system, you want the assurance that a surprise is not going to pop up. With Electronic Measurements' EMQ Series of Magic Modules, you have the assurance of dependable performance, since the design incorporates proven fixed frequency, forward converter technology with current mode control and a nominal frequency of 250 kHz. Another good reason to choose the Magic Module is size. The EMQ series also offers the highest power rating for any self contained 5-V output, high density, board mounted unit available.

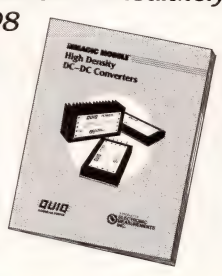
For example, the EMQ48-05-40, rated at 200 W, occupies a footprint of only 2.4" x 4.6" with a 0.625" profile, and a nominal input of 48VDC.

For a pleasant surprise, check these MAGIC MODULES features:

- *More watts per cubic inch than any other 40 Amp. converter*
- *Forward converter topology for proven reliability*
- *Fixed frequency (250 KHz) for EMI reduction and stability*
- *6 sided RFI shielding available*
- *RMS current reduced to negligible levels in a short circuit mode*
- *Unit latches off in an overvoltage or over temperature condition*
- *Operates in the N+1 Mode for system redundancy*
- *Standard units include outputs from 5 to 48 VDC, inputs from 10 to 300 VDC, 50 to 200 Watts power out*
- *Thermal characteristics allow for PC board mount with only natural connection up to 50 watts*

Best of all, you have the assurance that THE MAGIC MODULE comes from Electronic Measurements, a company with over 40 years of power conversion experience.

THE MAGIC MODULE brochure is yours for the asking. If you need information immediately, call TOLL FREE 1-800-631-4298 (In NJ, HI, AL and Canada 201-922-9300).



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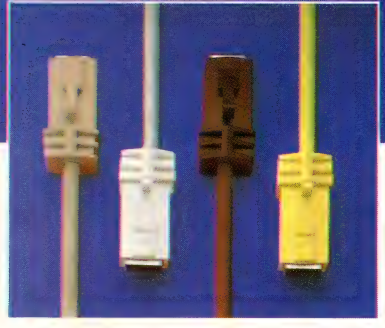
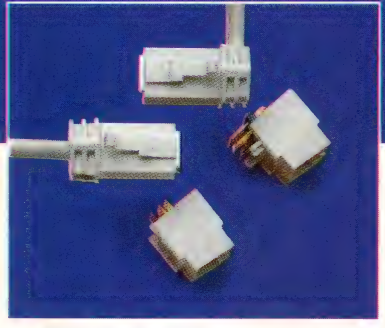
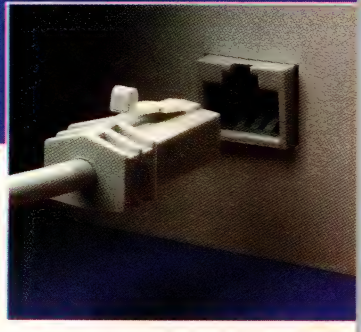


Any color.



Angled or straight.



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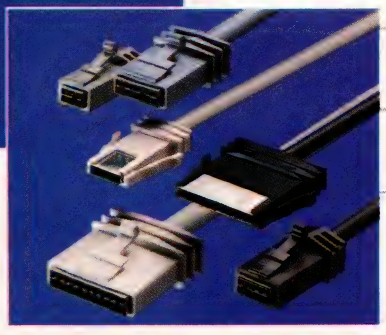

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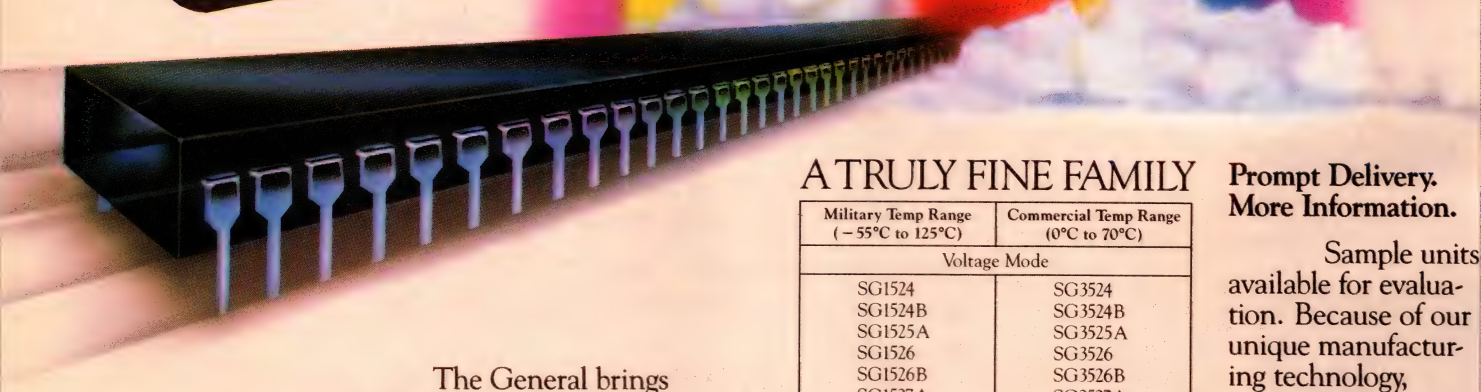

The General brings designers everywhere from everywhere the latest arrays of PWM's for an ever growing list of applications.

Newest PWM's include the SG1844/1845 Current-Mode PWM Controller, SG1528/1530 High Speed Current/Voltage Mode Controller, SG1526B and SG1529 Regulating PWM's, and SG1825 high-speed current mode PWM.

Silicon General PWM's are offered in voltage mode, current mode, and voltage and current modes. They are available in ceramic, plastic and surface mount. The General processes PWM's and supervisory circuits to 883B, Rev. C and S Level. All standard package types are offered including SOIC, PLCC, LCC, and flat pack.

Quality? You bet. And in very high volume too. MIL-M-38510 approval has been granted for our plant to produce JAN parts.

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SG1524B	SG3524B
SG1525A	SG3525A
SG1526	SG3526
SG1526B	SG3526B
SG1527A	SG3527A
SG1529	SG3529
Current Mode	
SG1825	SG3825
SG1842	SG3842
SG1843	SG3843
SG1844	SG3844
SG1845	SG3845
SG1846	SG3846
SG1847	SG3847
Current and Voltage Mode	
SG1528*	SG3528*
SG1530*	SG3530*

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SIGNALS & NOISE

"Fixable" kits are a "fixation" for him

Jon Titus's editorial "Design for fixability" (EDN, May 25, 1989) caught my interest because I've also built a number of Heathkit products—but with a different view of their fixability. They do work well (in fact, I'm writing this letter on my 11-year-old H-8 computer), but my experience fixing problems with them seems to be quite different from Jon's.

Let me relate the tales of repairing this H-8 computer. Back in the first days of home computers, an 8k-byte memory board was a big thing—I bought three of them with my H-8 computer kit. After putting the computer itself together, the next step was to put together a memory board so I could test things. To make a long story short, the first memory board failed to work at all—I couldn't even run the memory test in the ROM! Since it was under warranty, I let the technician at the local Heathkit store worry about what was wrong. Six weeks later when it was fixed, the technician was ready to swear at the double-sided pc board with plated-through holes after finding and replacing three defective IC sockets!

The H-8 itself contains a speaker that produces various beeps to indicate keypad activations, etc. One night shortly after I got the device working with the other memory boards, I was editing a program (audio-cassette I/O—no floppy drives at the time), and the computer began sounding off continuously. Resetting didn't do a thing. I followed every test in the manual's troubleshooting chart. I reached the box that said, "Your computer is up and running," although the speaker was still sitting there emitting its constant 2-kHz tone. Fortunately, the local Heathkit store was open that evening, so I made it just before the store closed at 9:00 pm. When I picked the equipment up a couple of weeks later, the [verdict was to] replace the 8080 and also the system controller chip.

I won't take the time or space to relate [the] problems when I added floppy-disk drives to the system, [but] when a flaky memory chip developed on a 16k board after I upgraded to a Z80 CPU board, I paid over $100 to get the chip replaced at the local store. Seems the chip worked with the 8080 CPU, but slight timing differences made the chip fail with the Z80 CPU. And Heathkit's technician wouldn't make the effort to isolate the bit that failed—he just replaced all eight chips in the bank at $12.50/chip (at a time when the same chips cost about $3.50 each in ads in *Byte*).

Heathkits designed for fixability? Maybe some are, but not the ones I've built!

Robert H French
Arlington, VA

Hot under the collar about cold-fusion editorial

After reading Jon Titus's "Weird science" editorial, which appeared in EDN June 22, 1989, I became very angry. I am an ME and have several patented inventions to my credit. I can only say that an editorial like that is very negative and puts down other scientists. Since cold fusion has been duplicated by three other groups of scientists, why the put-down? It seems to be a common malady among short-sighted and narrow-minded scientists, especially older and more entrenched physicists and professors with whom I have personal experience.

You can't seem to teach an old dog new technology. This [mind-set] will go on for centuries and will never change. Try to create some new invention, and everyone beats

you down. Try to do it yourself, and they club you down. Try to market it, and they destroy your home, family, and even cripple you physically. You can't suggest new ideas that the old guard will accept. So much of true scientific [research] is suppressed, it is ridiculous. The universities and colleges are so eager to get grants to falsely prove false theories, it's sickening. I invent new mechanical devices, and some day they will be on the market.

This letter is sure to cause some controversy, and so are free-energy devices, so let's hear from the engineers who have had the same problems and experiences I've had.

Alfred H Berger
RB Engineering
San Diego, CA

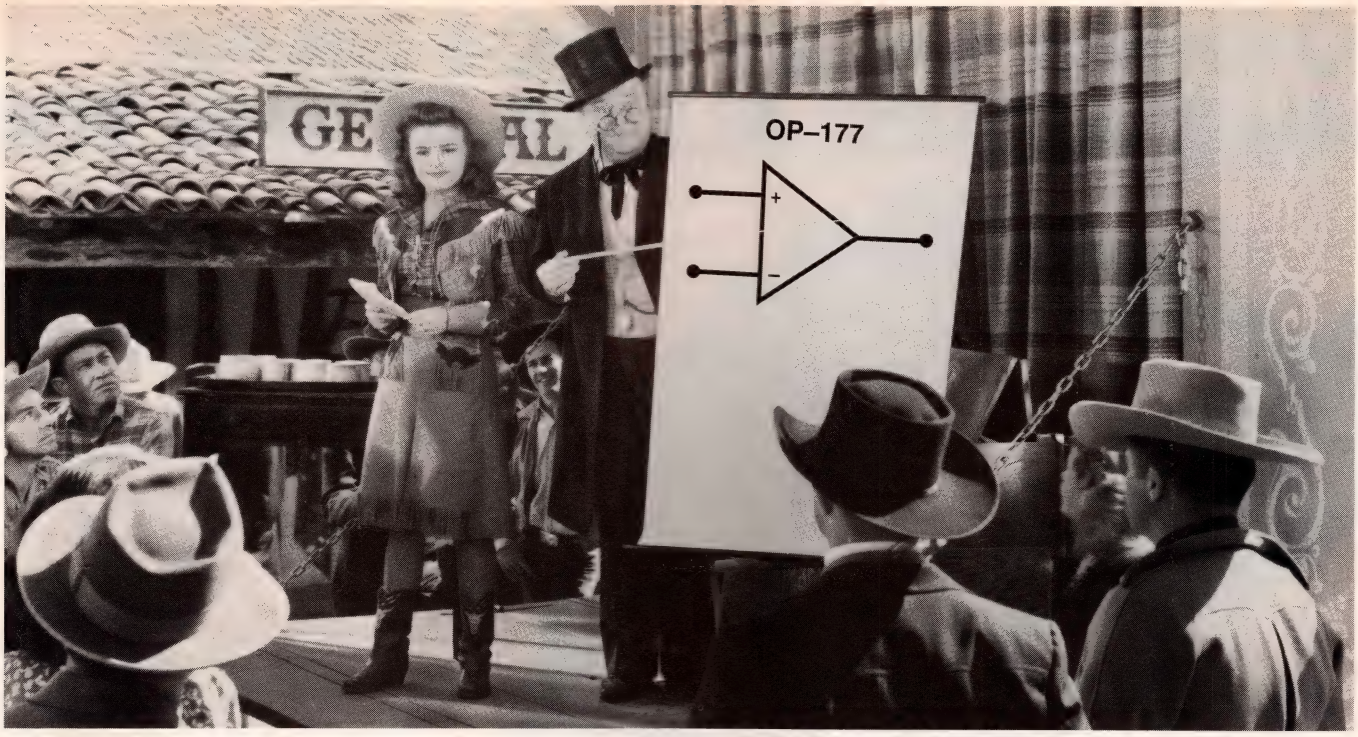
(Ed Note:) Mr Berger misses the point. The point is that, although cold fusion may be real, the Utah researchers jumped the gun and made their experiments look like the solution to our energy problems. They can research cold fusion all they want, but they should substantiate it and back it up with good science.)

Correction

In **Table 2** of EDN's Special Report in the June 22, 1989, issue (pg 152), the gate delay for Analog Devices' mixed analog-digital standard cells should have read 6 nsec, rather than 6 μsec.

YOUR TURN

EDN's Signals and Noise column provides a forum for readers to express their opinions on issues raised in the magazine's articles or on any topic that affects the engineering industry. Send your letters to the Signals and Noise Editor, 275 Washington St, Newton, MA 02158. We welcome all comments, pro or con. All letters must be signed, but we will withhold your name upon request. We reserve the right to edit letters for space and clarity.



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PMI's twenty years as the leader in precision op amps bring you a true cost and performance breakthrough – the OP-177!

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	Guaranteed Vos (μV)	TCVos (μV/°C)	*Guaranteed* Temp. Range	Price (100 pc.)
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PMI's all new three-hour Analog Applications Seminar is coming this Fall. In addition to complete course notes, attendees will receive a floppy disk with PMI's New Advanced SPICE Op Amp Models. For more information, call our toll-free number 800-843-1515.

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CIRCLE NO 42

IN TOUCH WITH TOMORROW

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Less	More
⊖ space	current handling ⊕
⊖ weight	temperature ⊕
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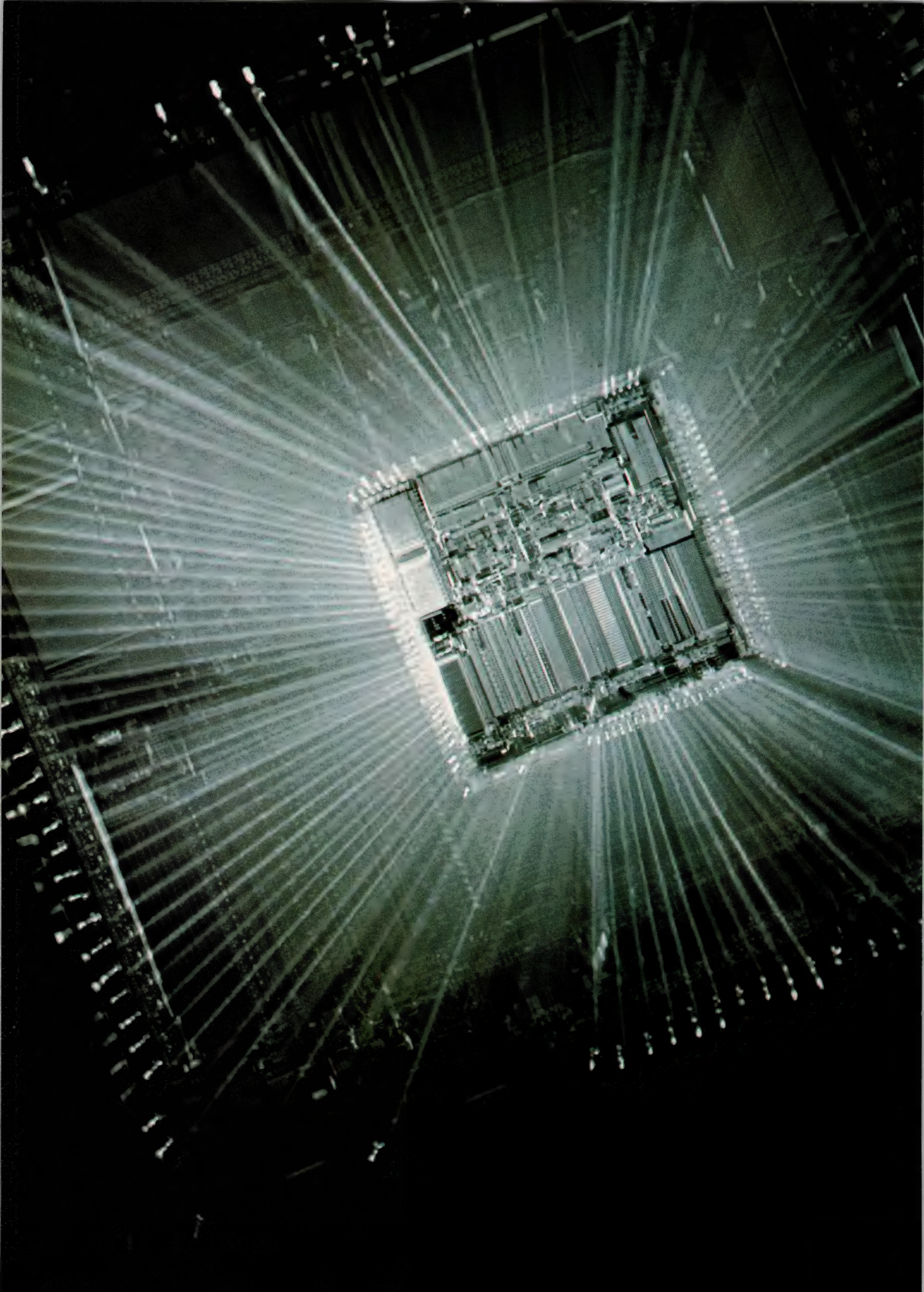

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In the computer industry with its never ending goal of miniaturization, nothing is more important than using the highest performance engineering plastics.

And Amoco Performance Products provides the highest performance resins that make down sizing of components possible.

Our Xydar® resin, for example, has excellent dimensional and creep stability at elevated temperatures. It is a natural choice for higher density connectors and IC sockets. Plus, it has low ionic contamination and is ideal for surface mount assembly.

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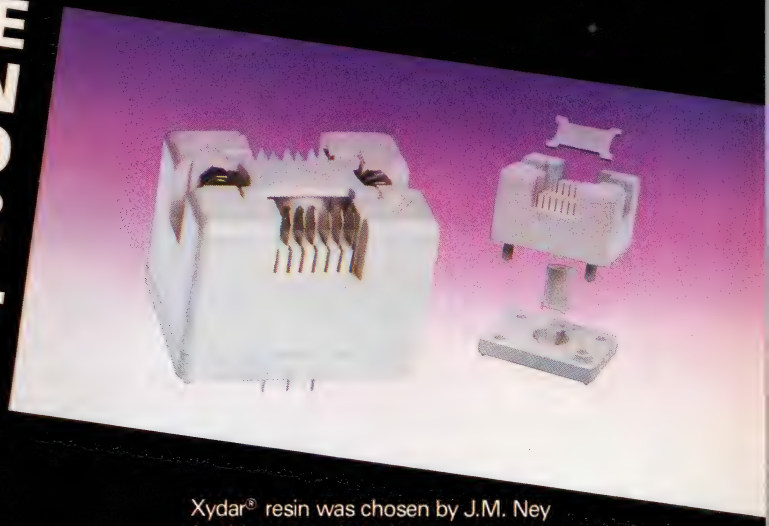

Xydar® resin was chosen by J.M. Ney for this extremely high temperature burn-in socket because of its dimensional and creep stability at temperatures above 200°C.

CIRCLE NO 44

CALENDAR

1989 Annual Conference of the International Federation of Consulting Engineers, Washington, DC. Jeanne Quick, American Consulting Engineers Council, 1015 Fifteenth St NW, Washington, DC 20005. (202) 347-7474. September 24 to 27.

Expo SMT International, Las Vegas, NV. Expo SMT, Box 1869, Los Gatos, CA 95031. (408) 354-0700. FAX 408-354-1036. September 25 to 27.

Hybrid Microcircuit Technology (short course), Bethlehem, PA. National Training Center for Microelectronics, Northampton Community College, 3835 Green Pond Rd, Bethlehem, PA 18015. (215) 861-5450. FAX 215-861-5373. September 25 to 29.

Diskcon, San Jose, CA. Julie Sunseri, 710 Lakeway, Suite 170, Sunnyvale, CA 94086. (408) 720-9352. FAX 408-736-2523. September 26 to 27.

IEEE International Conference on Computer Design (ICCD '89), Cambridge, MA. Giovanni De Micheli, Center for Integrated Systems, Room 129, Stanford University, Stanford, CA 94305. (415) 725-3632. October 2 to 4.

Electronic Imaging Conference East, Boston MA. MG Expositions Group, 1050 Commonwealth Ave, Boston, MA 02215. (800) 223-7126; in MA, (617) 232-3976. October 2 to 5.

20th Korea Electronics Show, Seoul, Korea. Joseph Burke, US Department of Commerce, Washington, DC 20230. (202) 377-5014. October 7 to 12.

Policy and Parity: The Future of US-Japan High Technology Trade Policy (symposium), Boston, MA.

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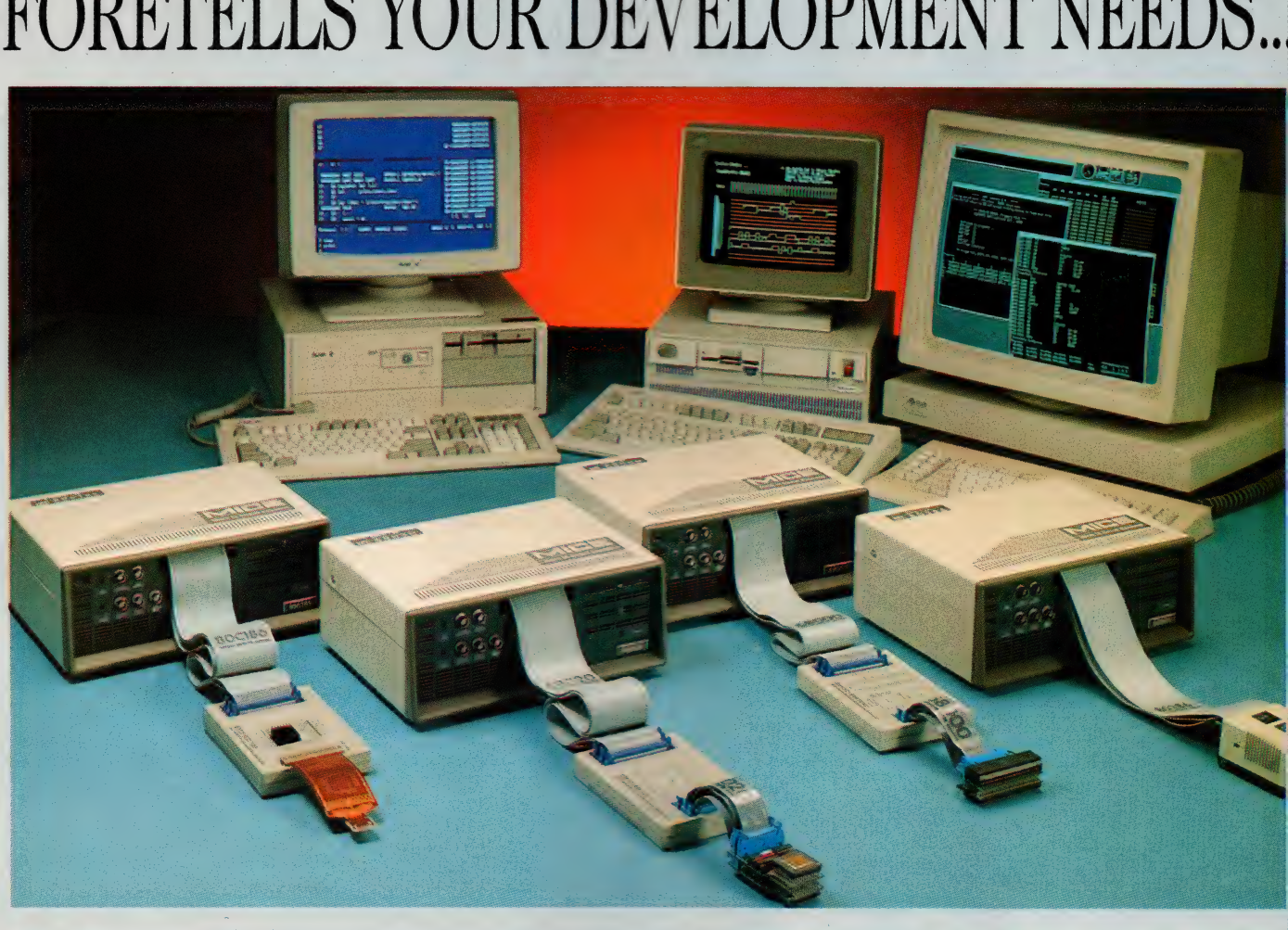

MICROTEK offers a complete line of MICE (Micro-In-Circuit-Emulator) for most popular 8, 16 and 32-bit microprocessors. These series of MICE are capable of debugging high speed targets without accumulating wait state, e.g. 25 MHz for 68020, 16 MHz for 68000/80C186. Protected Mode in 80386, coprocessor emulation in 16/32 bit series and bus/execution breakpoints in all series, are few examples of MICE powerful emulation features designed to meet advanced development needs.

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8-BIT	8085, 6809/E, Z80, NSC800, 6502F, 64180
16-BIT	80C86/88, 80C186/188, 80286, 68000/010, 68008, V20/30
32-BIT	80386, 68020 (25 MHZ)

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CALENDAR

Janet Fannon, Clearpoint Research Corp, 99 South St, Hopkinton, MA 01748. (617) 435-2301. October 12 to 14.

SECS Communications Seminar, San Jose, CA. GW Associates Inc, 1183 Bordeaux Dr, Suite 27, Sunnyvale, CA 94089. (408) 745-1844. FAX 408-745-6395. October 13.

Systems 89, Munich, West Germany. Gerald G Kallman, Kallman Associates, 5 Maple Ct, Ridgewood, NJ 07450. (201) 652-7070. FAX 201-652-3898. October 16 to 20.

Northcon/89, Portland, OR. Northcon/89, 8110 Airport Blvd, Los Angeles, CA 90045. (213) 772-2965. October 17 to 19.

Scan-Tech '89, San Jose, CA. Jane Yallum, AIM USA, 1326 Freeport Rd, Pittsburgh, PA 15238. (800) 338-0206. FAX 412-963-8753. October 17 to 19.

Supercomputing World, San Francisco, CA. MG Expositions Group, 1050 Commonwealth Ave, Boston, MA 02215. (800) 223-7126; in MA, (617) 232-3976. October 17 to 20.

Unix Expo '89, New York, NY. National Expositions Co, 15 W 39th St, New York, NY 10018. (212) 391-9111. FAX 212-819-0755. November 1 to 3.

Wescon/89, San Francisco, CA. Wescon/89, 8110 Airport Blvd, Los Angeles, CA 90045. (213) 772-2965. FAX 213-641-5117. November 14 to 16.

VMEbus in Industry, Paris, France. VMEbus International Trade Association, Box 192, NL-5300 AD Zaltbommel, The Netherlands. 31-4180-14661. FAX 31-4180-15115. November 21 to 22.

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Fluke 45

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0.05% basic dc current accuracy	*Optional PC Software for RS-232 applications*
1 MHz frequency counter	*Optional IEEE-488 interface, battery pack*
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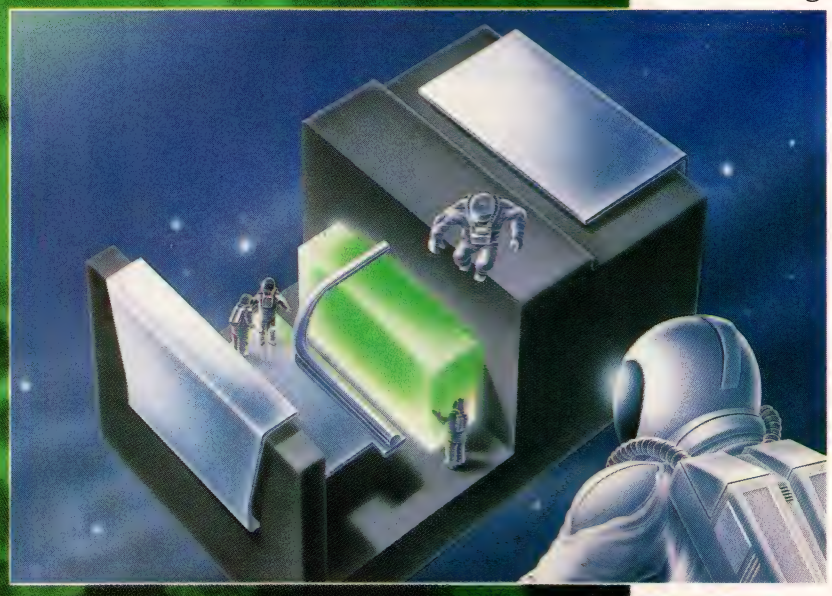

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A potpourri

Don't switch

At least one member of the Committee of Concerned EEs advocates switching from engineering to almost any other career. That's poor advice; in spite of uncompensated overtime and a less than professional image, engineering can still be a rewarding career. In fact, an exodus from engineering could have the opposite effect to the one the CCEE's Irwin Feerst wants. If today's engineers left for other careers, engineering work would go quickly overseas—to Europe and Asia—and that's an anathema to Feerst and to most US engineers. Engineers should work to improve their profession. Things aren't so bad that it's time to quit.

Let industry do it

As Senators and Congressmen debate the annual military budget and how to cut it, they ought to look at the military's dismal record in using military technology for civilian applications. The very high-speed integrated-circuit (VHSIC) program is an example of advanced technology developed for military use. Unfortunately, not one of the Phase II VHSIC suppliers—Honeywell, IBM, and TRW—has any plans for commercial use of its advanced IC technology. Perhaps future military-technology efforts should include funds for commercialization of developments; or maybe the government should let commercially oriented businesses do the technology-development work.

Hooray for IBM, sort of . . .

I'm pleased to read that IBM is producing 4M-bit dynamic RAM (DRAM) chips in the US. It just goes to show that US technology can compete against foreign technology when management is committed and has enough money to fund the work. However, it's unlikely that IBM will sell its DRAM ICs on the open semiconductor market, so US computer manufacturers such as Compaq and Zenith will have to go to Asia for their 4M-bit chips. It's a shame that a US company has an advantage that won't help other US manufacturers.

Southern trouble

At a time when we're concerned about the direction of the People's Republic of China, we should also spend time looking closer to home. In Central and South America, poverty is rampant, and inflation rates are as high as 1000% per year. According to *Business Week*, hundreds of people died in Venezuela in February during "anti-austerity" riots. China makes the news—Venezuela doesn't. Many people who live south of the US-Mexico border look to the US for salvation. In fact, many of them sneak into the US daily, seeking relief from war, repression, and poverty. It has been said that charity begins at home; it also begins with our neighbors. The Simpson-Rodino Bill makes it more difficult for illegal immigrants to stay in the US, but it doesn't weaken their aspirations to come to the most economically powerful country in the world. It's time for concerted action to help our southern neighbors and friends.

Jesse H Neal
Editorial Achievement Awards
1987, 1981 (2), 1978 (2),
1977, 1976, 1975

American Society of
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Jon Titus
Editor

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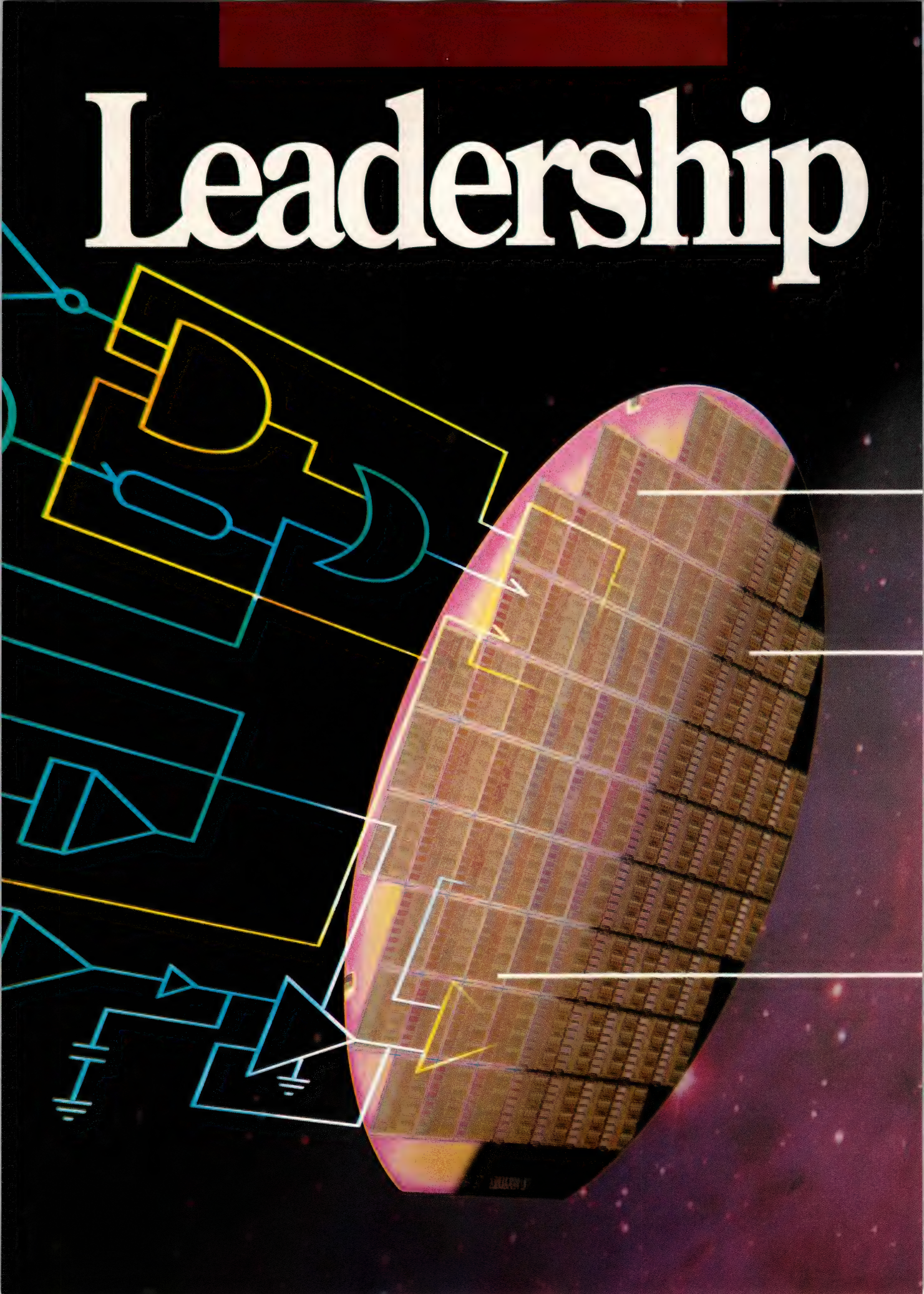

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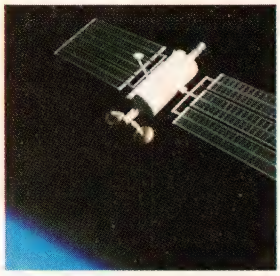

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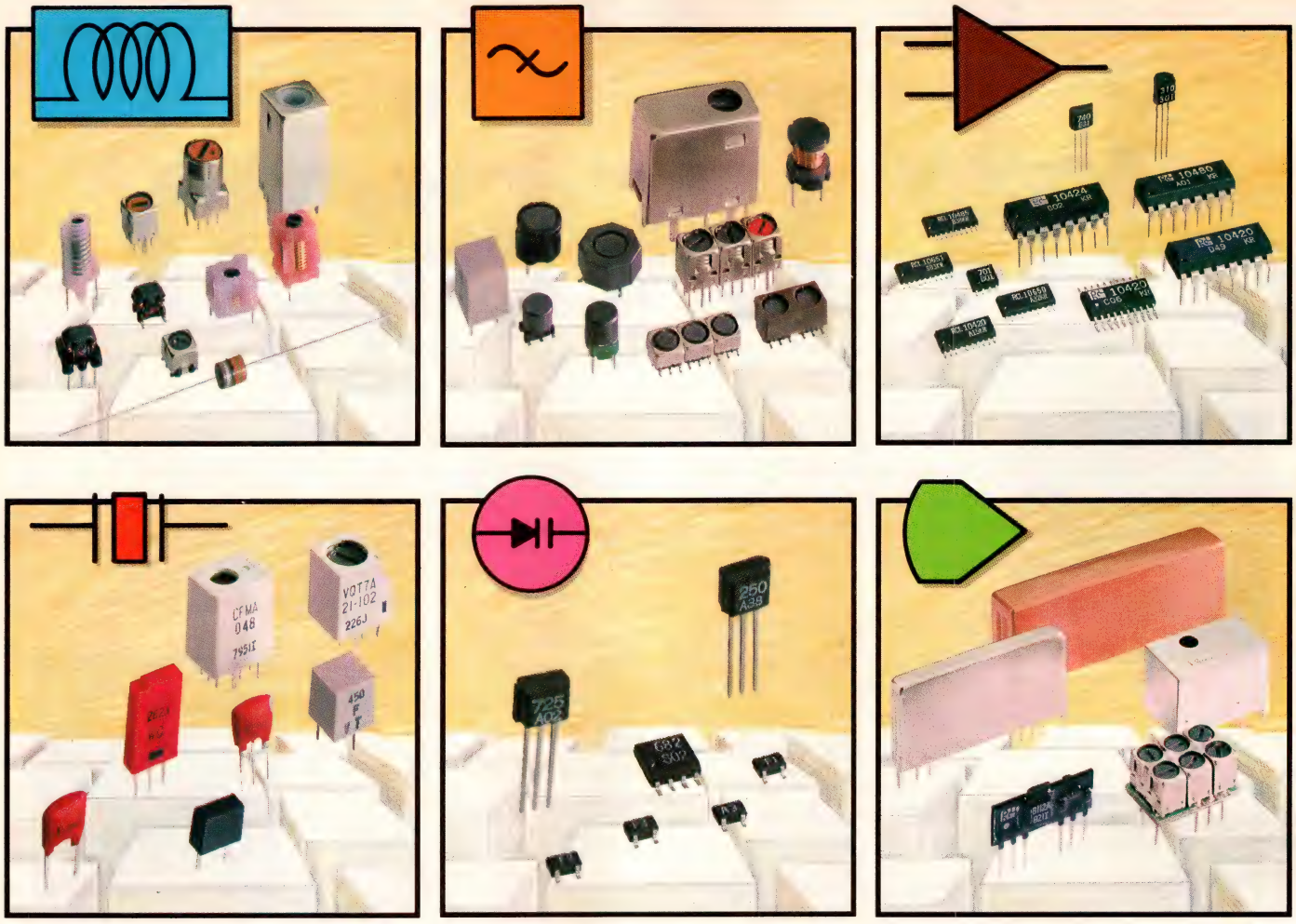

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CIRCLE NO 54

MOTOR-CONTROL/DRIVER ICs

Dedicated circuits suit a wide variety of tasks

Today's motor-control ICs are tailored to specific motor-speed and position-control applications, extending circuit choices and performance levels for your special requirements.

Dave Pryce,
Associate Editor

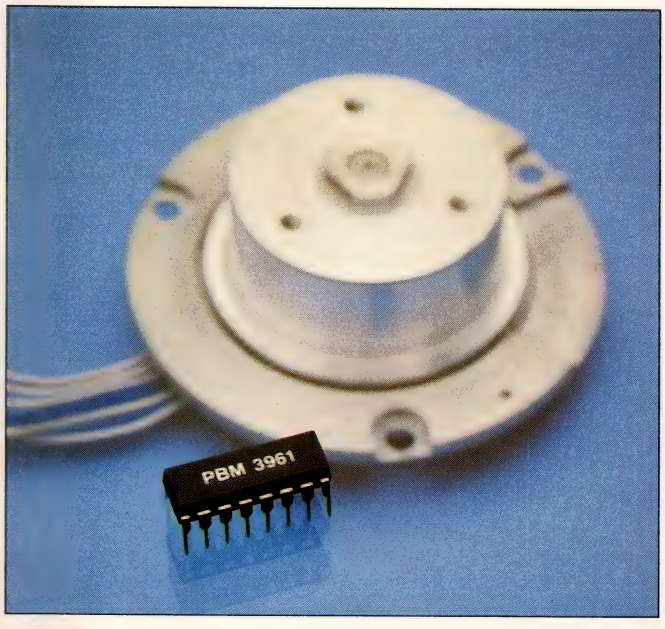
Time was when designers of motor-control circuits were forced to put together an unwieldy collection of discrete components in order to satisfy their requirements. The proliferation of computer peripherals such as disk drives and printers, however, greatly expanded the variety and number of applications for these dedicated circuits. As a result, early in this decade, manufacturers rapidly expanded the range of complete circuits specifically dedicated to the task of providing high-performance motor-speed and position control.

Probably the most successful of the first-generation, mass-produced ICs to provide dedicated control and drive for stepper motors was the PBL3717 from Ericsson Components. Introduced in 1982 under the RIFA logo, the PBL3717 was originally a custom circuit for Husqvarna, a Swedish sewing-machine manufacturer. At the time, the PBL3717 outperformed all other circuits in terms of achievable torque and stepping speed, and it soon found a home in disk-drive applications.

Still popular today, the PBL3717 comes in a 16-pin batwing DIP and provides switch-mode current regulation (chopper drive) for one winding of a bipolar stepper motor. The PBL3717 features full- and half-step modes, digitally selectable current levels, a 10 to 45V operating range, and a maximum current rating of 1.0A (0.8A recommended). The IC costs $1.38 (1000).

Others jump on the bandwagon

Quick to recognize a good thing, both Unitrode and Cherry Semiconductor introduced their own versions of the PBL3717 under their respective UC and CS prefixes. Later, SGS-Thomson and others also offered pin-compatible equivalents. Moreover, all of these manufacturers—including the originator, Ericsson—began upgrading the original 3717 to handle higher currents. Dual versions in various package options



Three-phase controller chips, *such as this PBM3961 from Ericsson Components, are commonly used for spindle-speed control in Winchester disk drives.*

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THE WESTCOR STAKPAK™. NEW GENERATION 250 TO 1200 WATT SINGLE OR MULTIPLE OUTPUT OFF-LINE SWITCHER. 3.2 X 5.5 X 11.4 INCH CASE. FAN-COOLED.

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The StakPak's 8 module output section can be factory configured in virtually an infinite number of voltage, current and power combinations. Special models providing between 250 to 1200 watts and outputs from 2 to 95 VDC are available.

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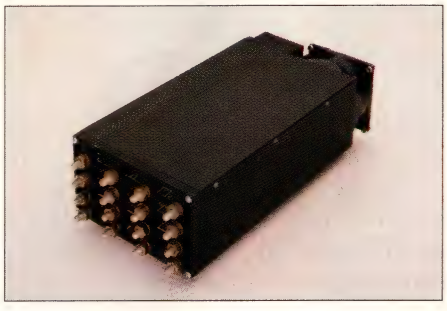

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(110/220 VAC input)

Model	Output Voltage (VDC) and Maximum Current (amperes) per Channel				
	#1	#2	#3	#4	#5
Single Output					
SP1-1801	2 @ 240				
SP1-1802	5 @ 240				
SP1-1803	12 @ 100				
SP1-1804	15 @ 80				
SP1-1805	24 @ 50				
SP1-1806	28 @ 42				
SP1-1807	48 @ 25				
Dual Output					
SP2-1801	2 @ 120	5 @ 120			
SP2-1802	5 @ 120	5 @ 120			
SP2-1803	5 @ 120	12 @ 66			
SP2-1804	12 @ 66	12 @ 66			
SP2-1805	15 @ 53	15 @ 53			
Triple Output					
SP3-1801	5 @ 180	12 @ 16	12 @ 16		
SP3-1802	5 @ 150	12 @ 33	12 @ 16		
SP3-1803	5 @ 180	15 @ 13	15 @ 13		
SP3-1804	5 @ 150	15 @ 26	15 @ 13		
Quad Output					
SP4-1801	5 @ 150	12 @ 16	12 @ 16	5 @ 30	
SP4-1802	5 @ 150	15 @ 13	15 @ 13	5 @ 30	
SP4-1803	5 @ 150	12 @ 16	12 @ 16	24 @ 8	
SP4-1804	5 @ 150	15 @ 13	15 @ 13	24 @ 8	
Five Output					
SP5-1801	5 @ 120	12 @ 16	12 @ 16	5 @ 30	24 @ 8
SP5-1802	5 @ 120	15 @ 13	15 @ 13	5 @ 30	24 @ 8

Total output power may not exceed 1200 watts for any model, single or multiple output. Lower power StakPak models are available. Please contact the factory.

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also became available.

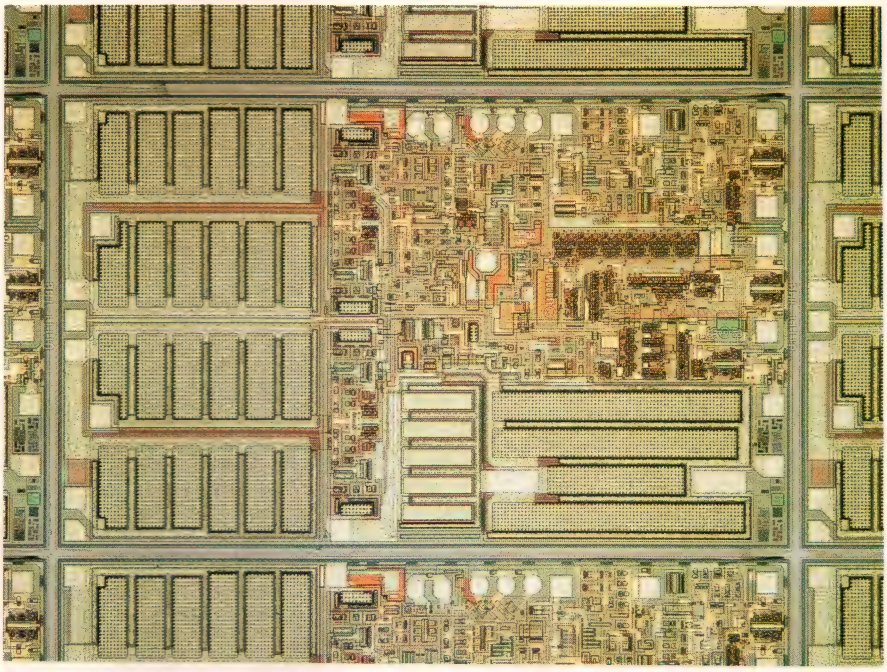
Because the derivatives of the original PBL3717 are seemingly countless, we'll discuss only the most significant ones. Ericsson offers two upgrades to its original 3717. The PBL3717/2 raises the current rating from 1.0 to 1.2A, and in addition to the pin-compatible 16-pin DIP, it's also available in a 28-pin plastic leaded chip carrier (PLCC) for surface-mount applications. The PBL3770A, rated at 1.8A, also comes in a 16-pin DIP and a 28-pin PLCC, but it doesn't contain the top-side diodes in the output bridge circuit—a consequence of its higher current rating.

Cherry Semiconductor (CSC) and Unitrode Integrated Circuits also offer upgrades to the 3717. The CS-3717A from CSC is identical to the PBL3717/2, and its CS-3770A—although rated at a slightly lower current of 1.5A—is otherwise identical to the PBL3770A.

The UC3770A/B from Unitrode is not only rated at 1.8A (like the PBL3770A), but also has the advantage of including on-chip diodes. The UC3770 features a saturation voltage of only 1.3V at 1A output current. The A and B versions are identical except for current-sense thresholds. The A version matches the older UC3717, and the B version is tailored for microstepping applications where 50, 71, and 100% of current levels are desirable.

Prices for these 3717/3770 upgrades vary by current rating and package options, but they all cost between $1.38 and $2.85 (1000). Look carefully at the data sheets as well as at the cost. Current rating, saturation voltage, package dissipation, and pin-compatibility all play a role in the selection process, and the performance tradeoffs aren't always apparent at a first glance.

In addition to the many choices available for single-circuit 3717/3770 devices, at least two vendors (Ericsson and Sprague) offer dual versions. Using these dual-circuit controllers, one IC can drive *both* phases of a bipolar stepper motor.



This unipolar stepper-motor driver, *the L6223 from SGS-Thomson Microelectronics, uses the company's BCD (bipolar, CMOS, DMOS) technology.*

Sprague's Semiconductor Group offers two devices, the UDN2916 and the UDN2917. The UDN2916 is a dual, full-bridge, PWM motor driver that operates over 10 to 45V. The output bridges, which include both ground-clamp and flyback diodes, are rated at 0.75A per channel. Similar to two PBL3717s, the chip includes thermal-shutdown circuitry. The UDN2916 is available in a 24-pin batwing DIP with a copper lead frame for $2.09 (1000). The device is also available in a 44-pin PLCC.

The UDN2917 is similar to two PBL3770s, and it's basically the same as the UDN2916, except for its higher current rating of 1.5A per channel. The UDN2917 is available in a 28-pin DIP with a heat-spreading copper slug and in a 44-pin PLCC. In the DIP package, the UDN2917 costs $3.27 (1000).

Ericsson Components also offers a dual controller/driver for bipolar stepper motors. The PBL3772 is targeted for high-density, surface-mount applications and is available only in a 28-pin PLCC. Ericsson is just going into production on the devices and estimates unit pricing at $3 (10,000). The internal circuitry of the PBL3772 is optimized for both high-accuracy microstepping performance and low power dissipation.

Rated at a maximum output of 1A per channel, the PBL3772 (**Fig 1**) handles the problem of power (heat) dissipation by using as many as six external diodes, and by its inherent reduction of the saturation voltage in the upper transistors of the output stages. At a total output current of 1.5A (2×0.75A), for example, the PBL3772 dissipates less than 2W—a significant improvement over two PBL3717s, which dissipate as much as 3.5W at the same output current.

Other applications are better served by a unipolar drive than a

Motor-control/driver ICs

bipolar drive. Many of the carriage motors and paper-feed motors in dot-matrix printers are unipolar wound, and several suppliers offer controller/drivers for these types of stepper motors. The L6223 from SGS-Thomson, an innovative supplier of power-management and motion-control circuits, is a notable example.

The L6223 operates from a 5V logic supply and a 9 to 46V motor supply. The output stages can deliver as much as 1A per phase to a 2-phase unipolar motor. Fabricated using the company's BCD (bipolar, CMOS, DMOS) technology, the L6223 has a parallel μP interface for full- or half-step motor rotation and a serial interface for 6-bit programming.

The internal 6-bit shift register lets you program the device for different duty cycles in the open-loop mode and for different chopping frequencies in closed-loop mode. When the current control is in the closed-loop mode, you can also select a reduced current level to optimize system efficiency. The L6223 comes in a 20-pin (16+2+2) power-DIP package that features four ground leads for heat sinking the chip to the pc board. It costs $2.50 (10,000).

Although the majority of positioning applications hum happily along under stepper-motor control, many require faster and more precise control. In today's high-density Winchester disk drives, for example, data is stored on tracks that are very close together. This increased density, coupled with access times in the 14- to 18-msec range, requires the improved head-positioning accuracy and faster operation usually obtainable only with a servo-controlled voice-coil motor.

One example of an appropriate servo controller is the EL2037 from Elantec. Because it has less than 5 mA of output offset current, the EL2037 allows precise positioning of the heads over the proper track during read/write operations. Further enhancing the accuracy is a class-AB output stage, which eliminates crossover distortion—an important consideration in embedded servo systems. The IC also provides logic-controlled head parking with a constant-velocity drive. This function uses the back EMF of the spindle motor as the only required voltage during power-down.

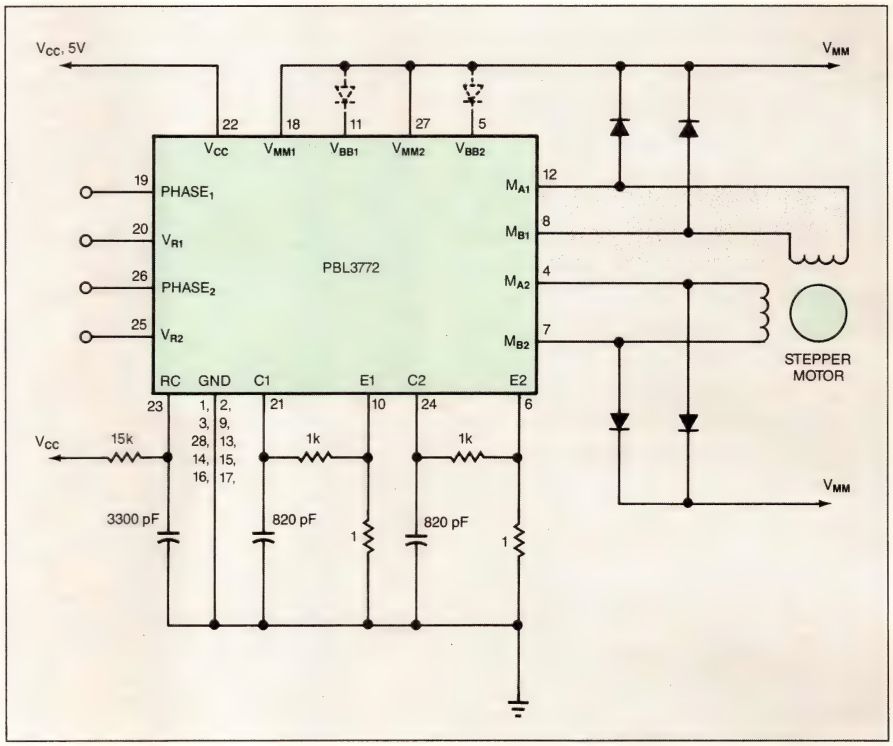


Fig 1—This dual-circuit controller/driver, *the PBL3772 from Ericsson, can drive both phases of a bipolar stepper motor. The device features high-accuracy microstepping, low power dissipation, and provides 1A of drive current per phase.*

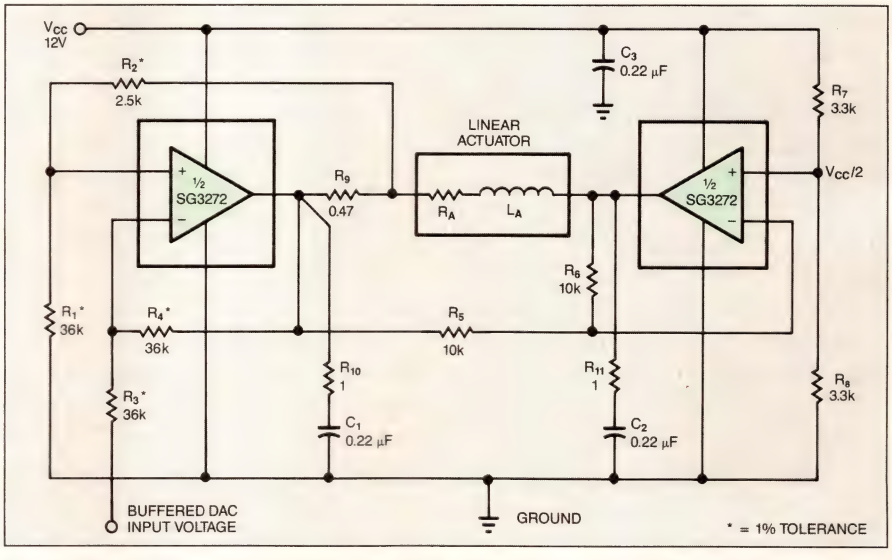


Fig 2—In this 3½-in. Winchester disk-drive application, *the SG3272 dual op amp from Silicon General drives a voice-coil motor (linear actuator).*

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Motor-control/driver ICs

The EL2037 provides the control and a minimum of 25-mA output drive, but it doesn't provide the actual motor drive. For this, you need two pairs of complementary bipolar transistors and four catch diodes. For a drive current of 1A, the MJE200 and MJE210 or the D44H11 and D45H11 are good choices. These devices are available from Motorola, SGS-Thomson, and others. The EL2037, which comes in a 20-pin DIP and a 20-pin SOIC package, costs $5 and $6.50 (100), respectively.

Rather than use discrete drivers (particularly where space is limited), many designers turn to monolithic power op amps to drive voice-coil motors. One example of a *dual* circuit is the SG3272 from Silicon General, which costs $2.15 (1000). In the application example in **Fig 2**, the SG3272 drives a voice-coil motor (linear actuator) in a 3½-in. Winchester disk drive.

The SG3272, which contains internal flyback diodes for use with inductive loads, has a maximum current rating of ±1A and a full output swing at ±500 mA. The dual op amp features thermal-shutdown protection and operates from a single supply of 4.5 to 13.2V or from a split supply. Other features include a power bandwidth of 200 kHz and an open-loop voltage gain of 90 dB. The SG3272 comes in an 8-pin DIP and a 20-pin SOIC package.

In addition to power op amps, Silicon General offers PWM controllers and other drivers for motor-control applications. Its SG3731, for example, is a PWM control circuit that operates from a ±3.5 to ±15V control supply and a ±2.5 to ±22V driver supply. The chip includes dual, 100-mA, sink and source output drivers. It features a 5- to 350-kHz oscillator range and adjustable deadband operation. The SG3731 is used in motor-driven servo systems to control precision positioning and speed. The device comes in a 16-pin ceramic DIP and costs $4.45 (1000).

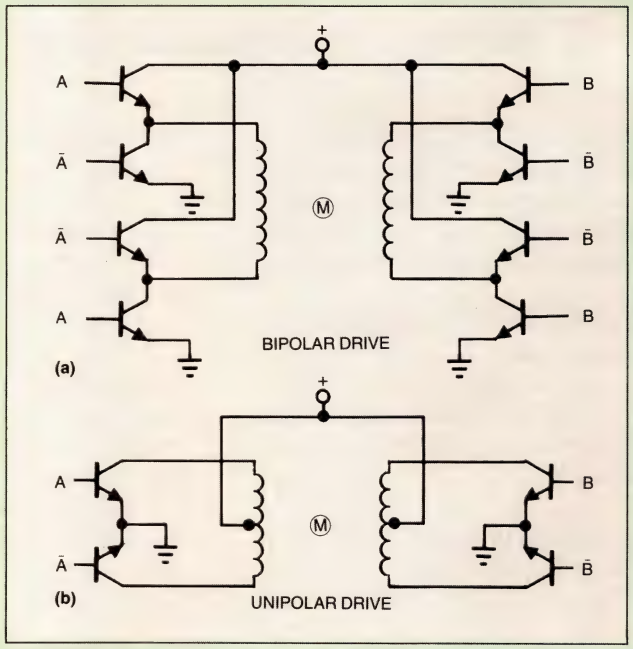
Another choice for servo control and drive is Cherry Semiconductor's Genesis 97100 semicustom array. The 97100 combines dedicated servo-driver circuitry with uncommitted array components. Included in the bipolar array are *two* power op amps, each capable of providing 1A max to the head-positioning actuator. It's also possible to configure the op amps to drive an external H-bridge for applications that require more than 1A of drive current.

The 97100 also includes a 2.5V (5.5V option) voltage reference with a trimmed accuracy of ±0.5%. It has a group of precision-resistor voltage dividers that you can use to set the undervoltage-detect trip

The differences between bipolar and unipolar drive

Bipolar drive **(a)** is used in motors with only one winding per phase. In these motors, the drive circuitry reverses the current in the windings, which reverses the stator flux. Bipolar-wound motors make maximum use of the windings, but they require a push-pull drive that uses four transistors for each winding. Bipolar drive warrants extra care in circuit design, to ensure that the series transistors don't conduct at the same time and short the power supply.

Unipolar-wound motors **(b)** have two coils per winding. The drive circuitry energizes one coil or the other to reverse the stator flux. Because it requires only two transistors per winding, unipolar drive is not only simpler, but also eliminates the critical-timing problem sometimes encountered in bipolar drive. Because of the extra coils, however, the wire diameter for a unipolar motor must be smaller than that used in a bipolar motor (for the same number of turns). Because the smaller wire increases the winding resistance, a unipolar motor has about 30% less torque at low step rates than a bipolar motor.



***Bipolar drive (a) requires four transistors to drive each winding** of a 2-phase motor. Unipolar drive **(b)** uses a center-tapped (2-coil) winding that requires only two transistors per winding.*

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points for both 5 and 12V supplies. In addition, undedicated components allow a maximum of 100 mA for retraction of the head using the back EMF of the motor. For designers that need a unique answer to their motor-drive problem, the 97100 semicustom approach is worth considering. NRE charges range from $5000 to $10,000, and unit prices from $4 to $5, depending on customer requirements.

The CY545 from Cybernetic Micro Systems is a different kind of chip that provides complete system control. The 40-pin CMOS device, which doesn't include power drivers, operates from a 5V supply and combines high-performance stepper-motor control with a variety of system interfaces. The CY545 can generate step rates to 27,000 steps/sec using pulse and direction signals, which provide adaptability to full-step, half-step, quad-step, or microstep applications. The chip's internal step register can count up to 16 million steps/motion. The device features both parallel and serial interfaces, as well as interfaces to an LCD and an LED display. The CY545 also provides support signals for writing and reading local external memory, and it costs $25 (1000).

Stepper motors and voice-coil motors dominate position-control applications, but brushless dc motors dominate speed-control applications, particularly in disk drives where you must use the smallest possible spindle motor because of space restrictions. With few exceptions, brushless dc motors use Hall-effect sensors for commutating the speed of the motor. Although 3-phase motors are almost exclusively used in high-performance applications such as disk drives, single-phase motors dominate low-cost applications, such as motors with small fans.

For these low-cost applications, Sprague Semiconductor offers the UDN3625 and UDN3626 Power Hall sensor/driver ICs. These devices provide complete control of single-phase, unipolar, brushless dc motors. The unique feature of these devices is the on-chip inclusion of a high-sensitivity Hall-effect sensor, which eliminates the need for an external sensor.

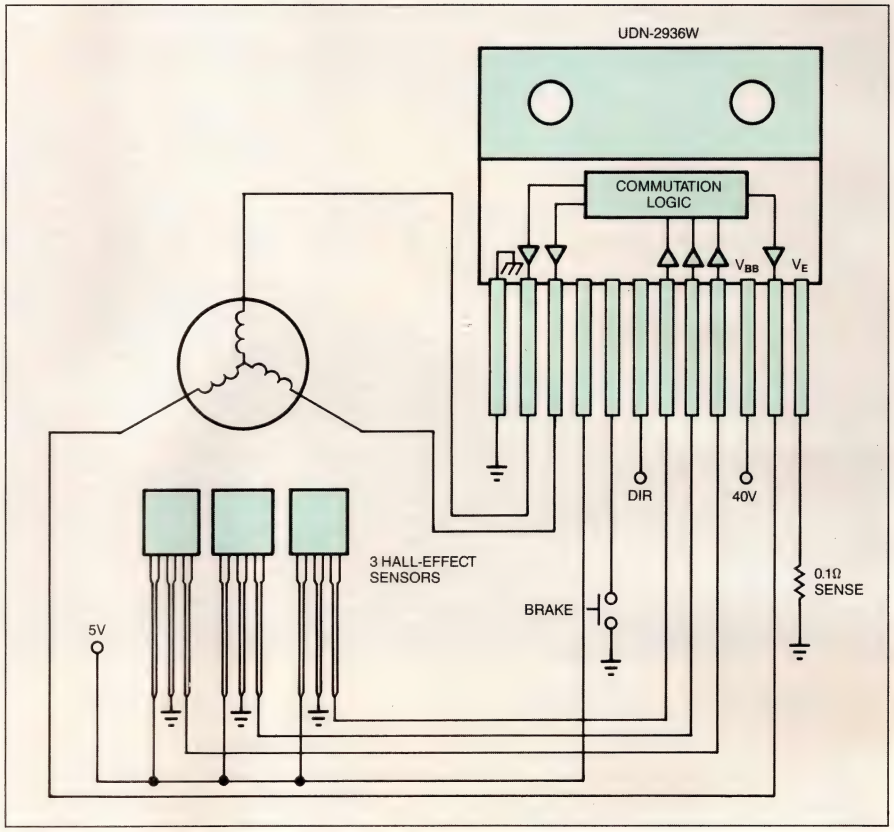
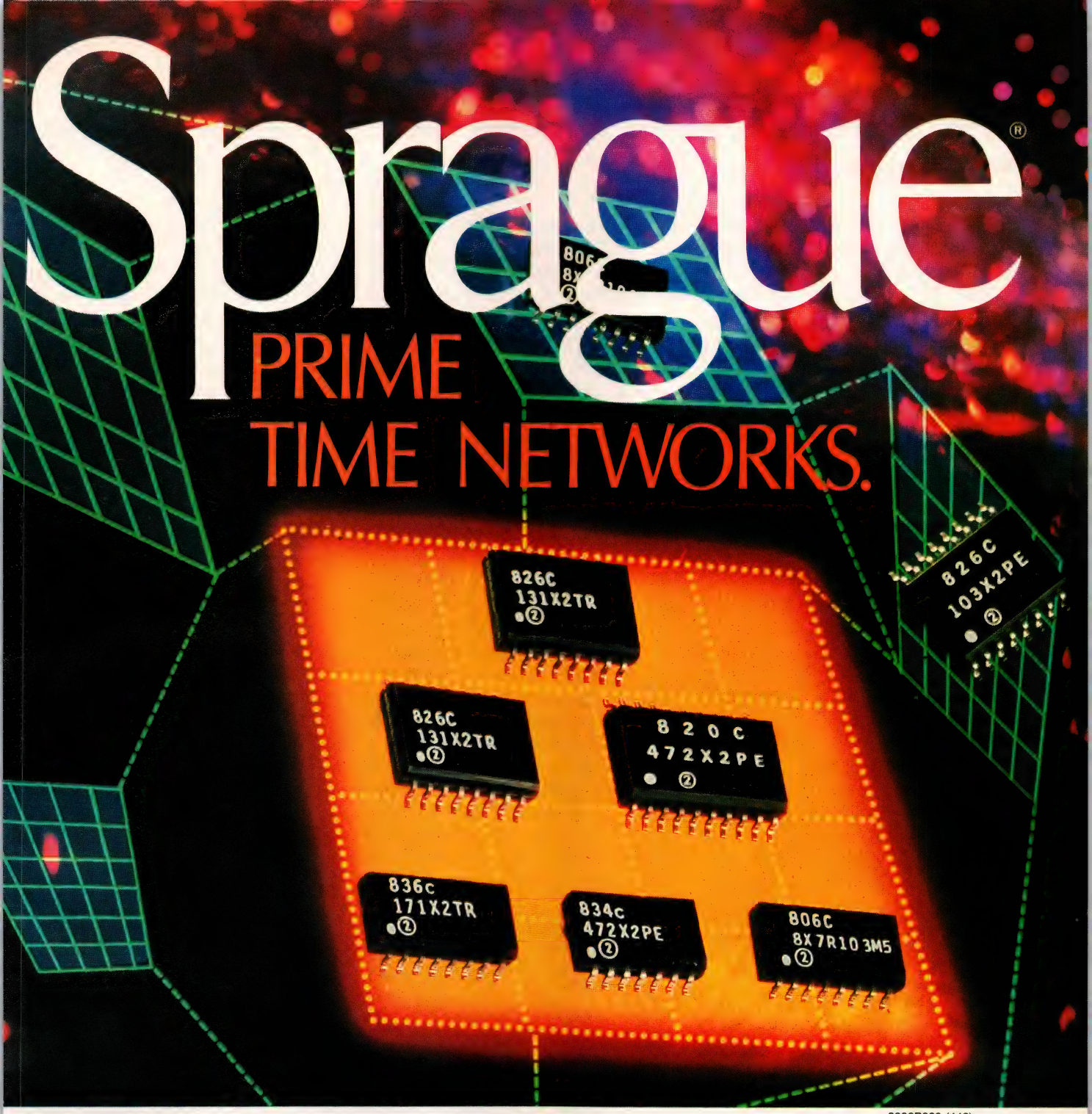


Fig 3—Combining logic and power, *the UDN-2936 from Sprague Semiconductor provides commutation and drive for a 3-phase, brushless dc motor.*

In addition to the Hall sensor, the monolithic ICs contain the control and commutating logic, a voltage regulator, two high-current npn outputs, and protection functions. These functions include thermal shutdown, output overcurrent limiting, and output transient-protection/flyback diodes. The UDN3625 is rated at 14V/1.0A for use with 12V motors. The UDN3626 is rated at 26V/0.45A for use with 24V motors. The devices are available in an 8-pin DIP for $1.01 (1000), and in a 14-pin SOIC package.

The single-phase controller from Sprague with the built-in Hall sensor may be labeled unique, but this isn't the case with 3-phase circuits. Although differences exist in performance and features, most 3-phase circuits are similar in that they use external Hall cells for commutation. Three-phase controller/drivers are available from a host of manufacturers, including Sprague, Motorola, Unitrode, Silcon Systems, Philips, and Ericsson.

The UDN-2936 from Sprague is a good example of a basic 3-phase driver. Combining logic and power, the UDN-2936 **(Fig 3)** provides commutation and drive for a 3-phase brushless dc motor. Each of the device's three push-pull outputs are rated at 45V and ±3A, and each has internal ground-clamp and flyback diodes. The IC features in-



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ternal commutation logic, PWM current control, and thermal shutdown protection.

The UDN-2936 is compatible with single-ended digital or linear Hall-effect sensors. A companion device, the UDN-2937, is compatible with linear differential sensors. The commutating logic is programmed for either 60° or 120° electrical separation. Both the UDN-2936 and the UDN-2937 cost $3.45 (1000) and come in a 12-pin SIP with a metal tab for heat sinking.

3-chip set fits high-power motors

Although many controller ICs provide sufficient output drive to power motors directly, some provide only the control circuitry. In such cases, you have to use external bipolar or MOSFET transistors. Many controller circuits also require external circuitry for speed control—apart from the normal commutation itself. A 3-chip set from Motorola Semiconductor is capable of driving high-power motors and satisfies all of these requirements. This 3-chip set (**Fig 4**) comprises the MC33035 brushless dc motor controller, the MC33039 closed-loop brushless motor adapter, and the MPM3003 3-phase bridge circuit.

The MC33035 is a second-generation controller that contains all of the active functions needed to implement an open-loop, 3- or 4-phase motor-control system. The MC33035 is pin-compatible with its MC33034 predecessor and offers additional features at a lower price of $2.88 (1000). Both devices include a rotor-position decoder for commutation sequencing; a frequency-programmable sawtooth oscillator; and an error amplifier and a PWM comparator, which both interface to the MC33039 closed-loop speed-control adapter.

Included in the MC33035 is a temperature-compensated 6.25V reference, which can supply power to the Hall-effect sensors and to the MC33039 adapter chip in closed-loop applications. The MC33035 also contains a control pin that lets you select 60/300° or 120/240° sensor phasing, and access to both the inverting and noninverting inputs of the current-sense comparator. The MC33035 is available in either 24-pin DIP or 24-pin SOIC packages.

The MC33039, which comes in an 8-pin DIP and costs $0.60 (1000), provides closed-loop operation for the MC33035. The MC33039 contains an inverter output for conversion between 60/300° and 120/240° sensor phasing, and provides speed regulation without the need for a magnetic or optical tachometer. The chip operates down to 5.5V for direct powering from the MC33035.

The MPM3003 is a complete 3-phase bridge consisting of three n-channel MOSFETs in the lower legs and three p-channel MOSFETs in the upper legs. The MPM3003 comes in Motorola's ICePAK, an isolated 12-pin SIP with an isolation rating of 2 kV and a peak-current capability of 25A. All six power MOSFETs have a V_{DS} rating of 60V. The n-channel devices have an on-resistance of 0.15Ω, and the p-channel devices are rated at 0.28Ω. Because the power transistors are isolated from the aluminum header, mounting the MPM3003 is simple and effective. The MPM3003 is expensive at $11.26 (1000), but it packs a lot of power in a convenient package.

Unitrode, another innovative supplier of motion-control circuits, offers a pair of devices for 3-phase applications. Its UC3625 has three push-pull, low-side drivers for driving power MOSFETs or Darlington transistors, and three 50V open-collector high-side drivers. The IC operates from 10 to 18V supplies and can control higher-voltage devices with external level-shifting components. The UC3625 performs fixed-frequency PWM control in either voltage or current mode and implements closed-loop speed control and braking. Its built-in Hall-sensor de-

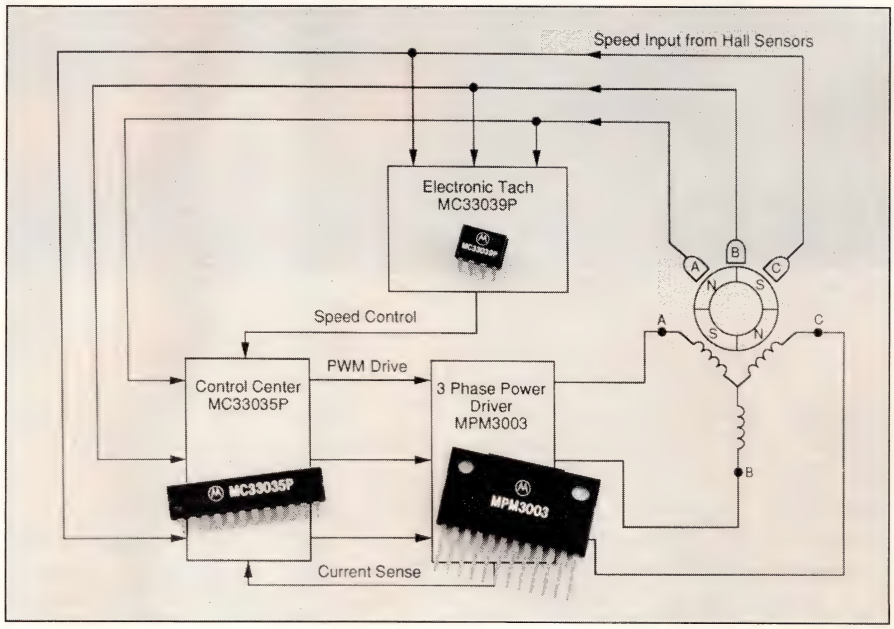

Fig 4—This 3-chip set provides a complete control system for brushless dc motors. *Available from Motorola, the MC33035 provides commutation and control circuitry; the MC33039 provides closed-loop speed control; and the MPM3003 3-phase MOSFET bridge provides as much as 10A of drive current.*

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Motor-control/driver ICs

code logic features protection against cross-conduction. Available in a 28-pin DIP or a 28-pin PLCC, the UC3625 costs $5.85 (100).

A second device from Unitrode, the UC3655, provides low-loss, linear 3-phase control. The UC3655 generates the phase timing for the Hall sensors and controls motor current in response to commands based on speed, position, and torque. The device uses external pnp transistors selected for low-saturation voltage as high-side drivers. The internal low-saturation npn transistors serve as low-side drivers. In this arrangement, the total sink-and-source saturation-voltage drop is less than 1V at a 1A load current—a significant advantage for low-voltage (12V) applications. The UC3655 comes in either a 15-pin power-tab package or a 28-pin PLCC, which cost $5.28 and $5.08 (1000), respectively.

In disk-drive applications, precise speed control is important—particularly in Winchester drives, which rotate at 3600 rpm. The SSI-32M594 from Silicon Systems regulates this 3600-rpm speed within an error factor of ±0.037%, using a 2-MHz clock as a reference. The monolithic IC controls 4- or 8-pole, 3-phase spindle motors in 5¼-in. and 3½-in. Winchester drives. Internal circuitry directly drives and decodes external Hall sensors.

The 32M594 uses external Darlington transistors or power FETs to drive either center-tap (unipolar) or noncenter-tap (bipolar) windings. The device's linear control loop controls the power drivers using pulse-amplitude modulation. The 32M594 operates from one 12V supply and offers a number of features including active braking, power-supply fault protection, and an on-chip digital filter. Available in a 20-pin DIP and a 20-pin SOIC package, the controller costs $7 (1000).

As previously mentioned, most 3-phase controller/drivers for brushless dc motors use external Hall cells for commutation. One exception to this commonly-used method is the TDA5140 from Philips Components, which uses the EMF in the motor coils for commutation. The IC works with star- or delta-wound motors and generates an output-drive current of 600 mA from an unregulated supply between 4 and 18V. The TDA5140 suits applications requiring very accurate speed control—including the scanner drives of videocassette recorders (VCRs) and camcorders, and the drive electronics of floppy and hard disks.

The TDA5140 (**Fig 5**) provides full-wave drive of a 3-phase motor using three push-pull output stages.

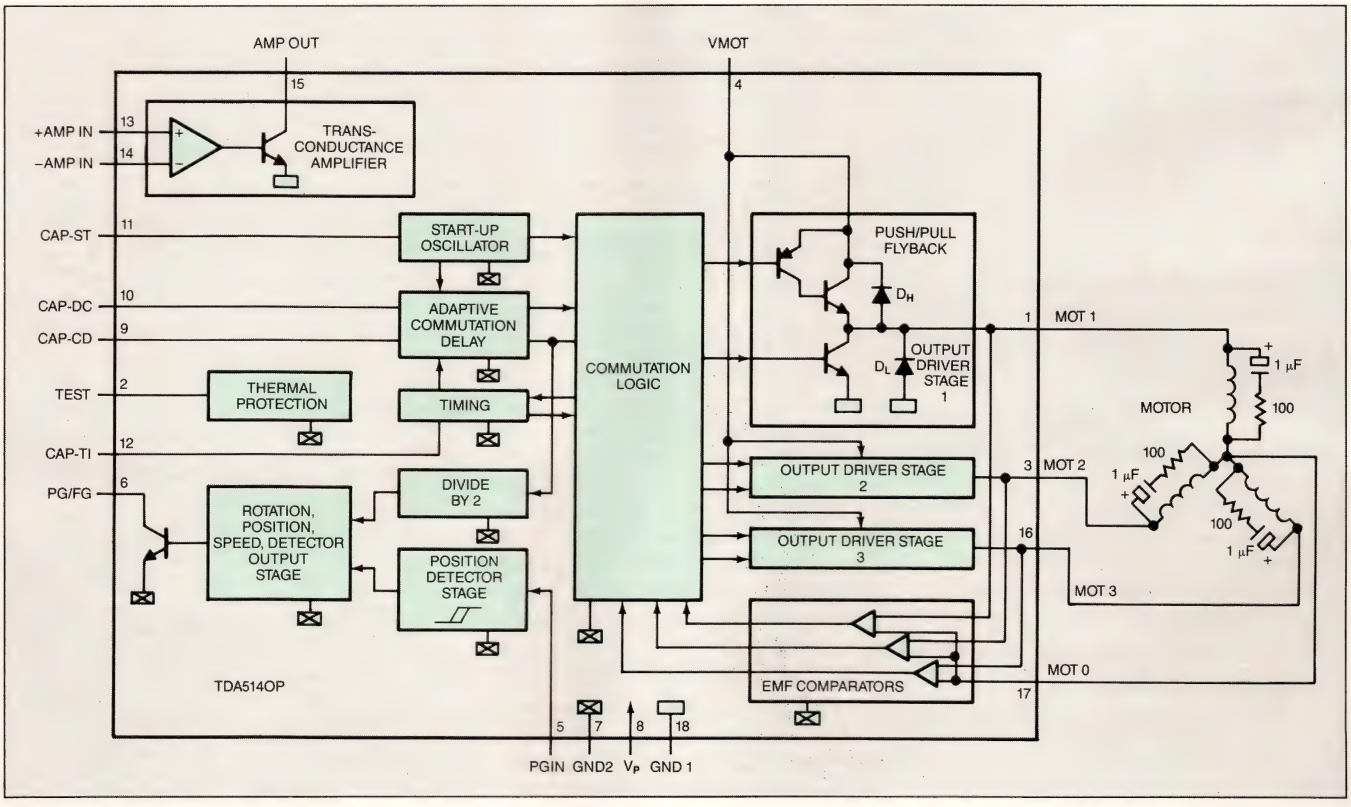

Fig 5—This sophisticated controller/driver *works with either star- or delta-wound motors. Manufactured by Philips and Signetics, the TDA5140 drives 3-phase, brushless dc motors using the EMF from the motor's coils to provide commutation.*

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In each of the six possible states, two outputs are active; one sources current and the other sinks current. The third output presents a high impedance to the motor. This high impedance enables measurement of the motor EMF in the corresponding motor coil by means of a comparator located at each output. The commutation logic is responsible for the control of the output transistors and the selection of the correct EMF comparator.

The zero-crossing in the motor EMF is used to determine the correct moment for the next commutation, that is, the change to the next output state. The delay, which depends on the motor loading, is calculated by the adaptive commutation delay block. The TDA5140 can also use the zero-crossings to provide speed information such as the tachometer FG (frequency generator) signal. A VCR scanner also requires a PG (position generator) phase signal. The circuit has an interface for a simple pickup coil. A multiplexer circuit combines the FG and PG signals. This digital signal, FG/PG, is available as an open-collector output.

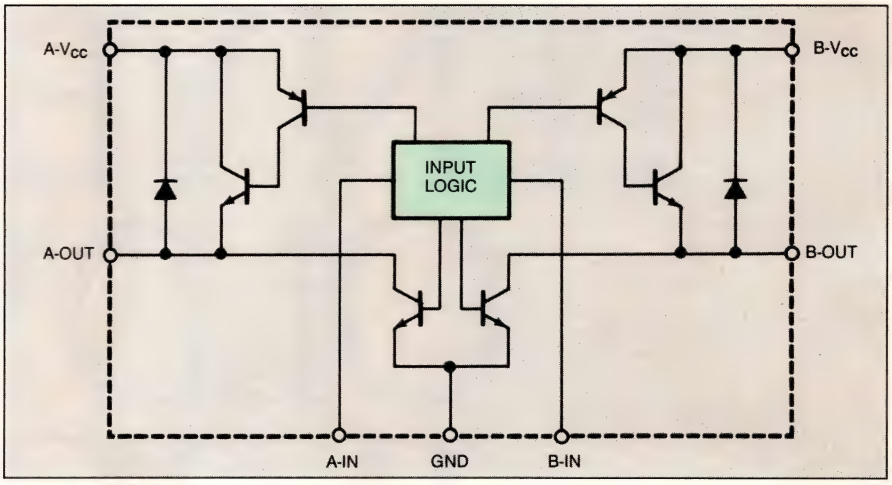

Fig 6—Designed for use in applications such as the front-loading mechanisms in VCRs, *the MB3763 from Fujistu Microelectronics can provide 300 mA of drive current to a bidirectional motor.*

Because of inductive loading, the output stages of the TDA5140 contain flyback diodes. The output stages are also protected by a current-limiting circuit and by thermal protection of the six output transistors. An uncommitted op amp generates a 40-mA output current and

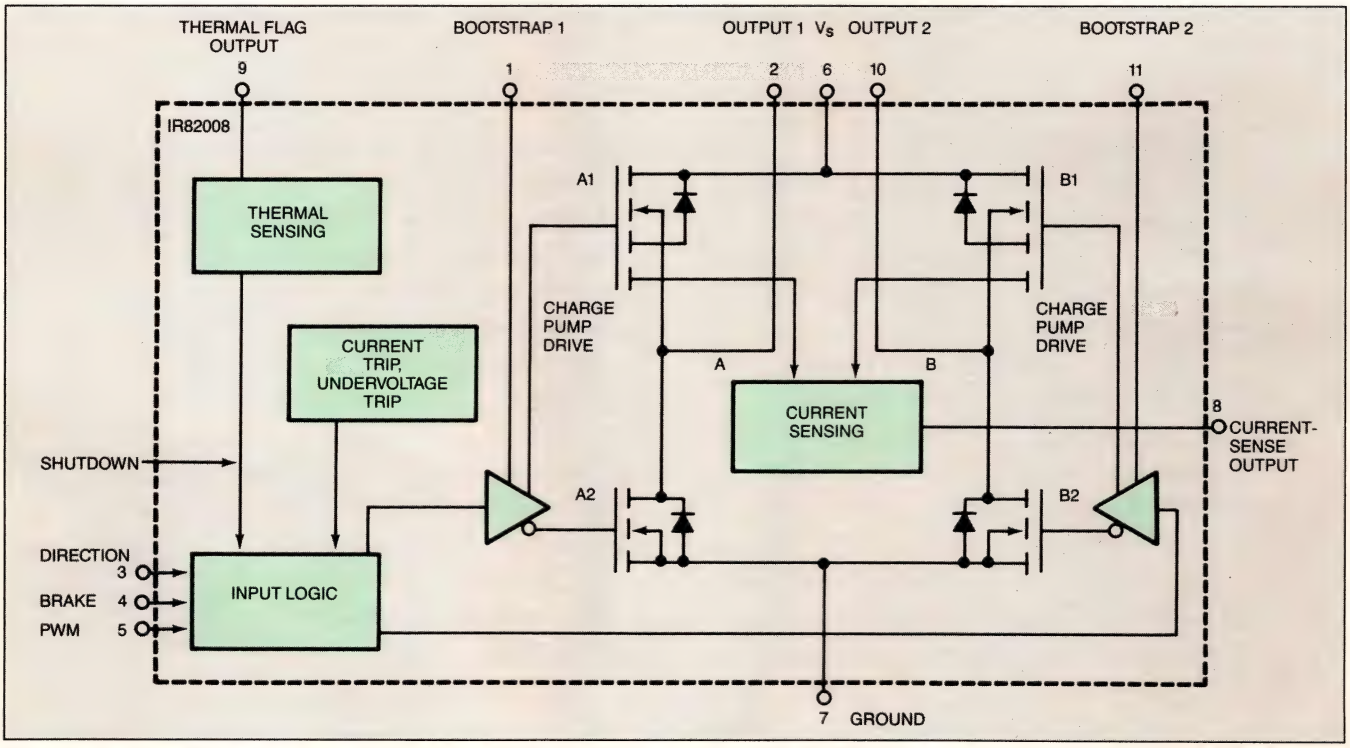

Fig 7—The result of a joint smart-power development effort, *the IR8200 from International Rectifer and the LMD18200 from National Semiconductor are identical devices. Using a combination of CMOS, bipolar, and DMOS technology, the devices operate at supply voltages to 55V and deliver as much as 3A of continuous current.*

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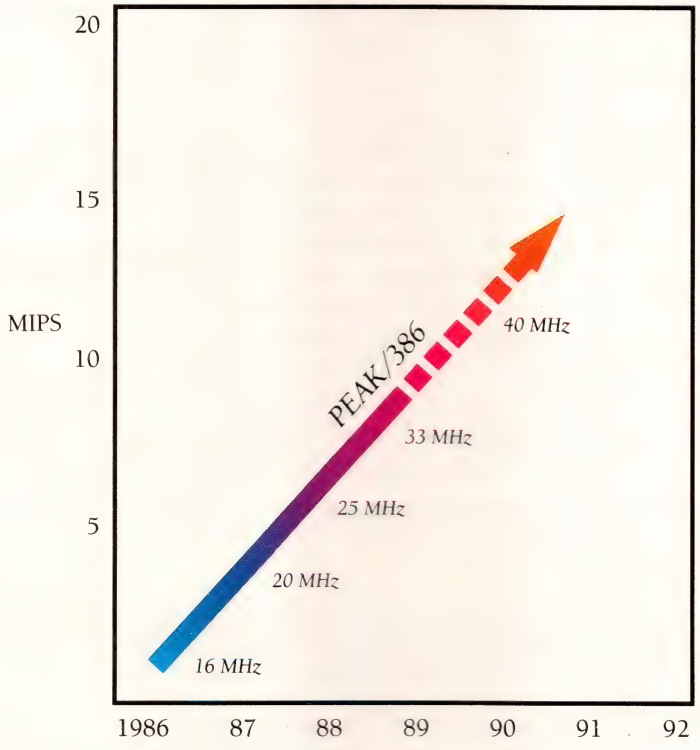

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Motor-control/driver ICs

can directly drive an external power transistor for speed-control circuits, or for level shifting in an SMPS (switch-mode power supply) drive. The TDA5140 is available in an 18-pin DIP with an internal heat spreader or in a 20-pin SOIC package with reduced power performance. Large-volume unit pricing is less than gld 4, although exact prices depend on the importing country. Residents of the US are advised to check with Signetics for pricing and availability.

Not all motor-control circuits include on-chip drivers. Fear not, however; you have a multitude of driver ICs from which to choose. Many of the controller suppliers already mentioned offer drivers in various configurations and in a range of current and voltage ratings. Typifying this variety and range are devices from suppliers not yet mentioned. For example, Fujitsu manufactures a simple low-current driver, and Texas Instruments offers more complex, high-current devices; National Semiconductor and International Rectifier offer a dual-sourced device.

The MB-3763 bidirectional motor driver from Fujitsu is used in such applications as the front-loading mechanism in videotape machines, or in autoreverse tape decks. Driven by a TTL signal, the MB-3763 (**Fig 6**) operates from a supply voltage of 4 to 18V and provides 300 mA of motor drive current when packaged in the available 8-pin SIP. In the 8-pin DIP and 8-pin SOIC alternative packages, the device is rated at 150 mA. The MB-3763, which contains built-in surge-protection diodes, features a standby capability when the input is off and a brake capability is in the stop mode. Prices start at $0.74 (10,000).

Texas Instruments' L298 and TLP298 are direct and improved replacements, respectively, for the L298 originated by SGS-Thomson. Operating from a 5 to 46V supply, these devices are dual H-bridge drivers (four half-H drivers) with a 2A output capability per driver. The improved TLP298 has a lower output-supply current than does the L298 (25 mA vs 38 mA with all outputs high, and 6 mA vs 13 mA with all outputs low). The TLP298 also

For more information . . .

For more information on the motor-control ICs discussed in this article, circle the appropriate numbers on the Information Retrieval Service card or use EDN's Express Request service. When you contact any of the following manufacturers directly, please let them know you saw their products in EDN.

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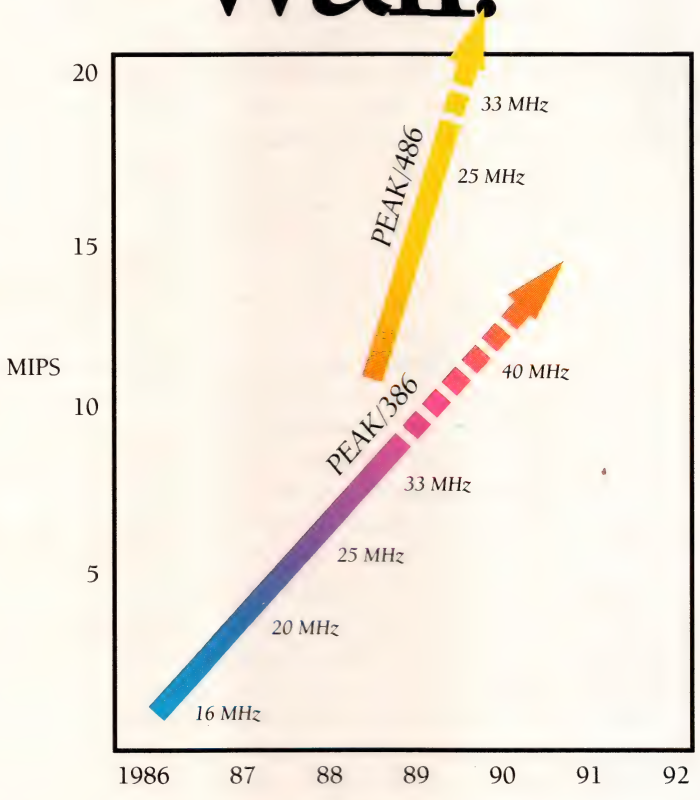

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TECHNOLOGY UPDATE

Motor-control/driver ICs

switches faster than the L298. Available in a 15-pin power-tab package, the L298 and TLP298 cost $4.49 (1000).

Capable of driving motors rated as high as ¼ hp, the LMD18200 from National Semiconductor and the identical IR8200 from International Rectifier are the first devices to emerge from a 5-year development agreement announced in late 1986. Aimed at the smart-power market, you can use these 55V/3A-rated H-bridge devices for driving motors in plotters, disk drives, printers, robotics and process-control equipment.

The IR8200/LMD18200 **(Fig 7)** combines CMOS and bipolar control circuitry with DMOS FET power devices. The device contains four DMOS switching transistors (with intrinsic feedback diodes) connected as an H-bridge. Also included are level shifting and drive circuits that interface between the output switches and the ground-level Direction, Brake, and PWM logic input signals that determine the on and off states of the output switches. The device also features a current-sensing circuit that provides an output that is proportional to the current.

Protective functions include a circuit that turns off the DMOS devices in the event of overcurrent or undervoltage conditions; a temperature-sensing circuit that provides an output warning when the maximum-rated temperature is approached; and an overtemperature shutdown circuit that operates at a set temperature margin above the warning level.

The IR8200/LMD18200 H-bridges, which operate from supply voltages of 12 to 55V, have output-current ratings of 3A (continuous) and 6A (peak). The on-resistance of each MOSFET in the bridge is typically 0.3Ω. Turn-on and turn-off switching times are typically 100 nsec. Packaged in an 11-pin power SIP, the devices have a power-dissipation rating of 25W at a case temperature of 75°C. The IR8200 costs $8.75 and the LMD18200 costs $8.26 (100).

As you can see from this survey of motor controllers and drivers, it's very likely that you'll find a device to suit your requirements. Bipolar drive, unipolar drive, 1- and 3-phase brushless motor drive, low-current drivers, high-current drivers, stand-alone drivers, and controllers with or without built-in drivers are all available from an ever-increasing number of suppliers. EDN

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WHAT'S COMING IN EDN

EDN's September 28 issue will feature a staff-written Special Report on 8- and 16-bit microcontrollers, which will identify trends in device design and cover a variety of situations that are affecting this competitive product area. Other articles in this issue will include

- The next installment of Bob Pease's troubleshooting analog-circuit series
- Thermostats in pc-board packages.

Next month, look for stories on liquid crystal displays and graphical software interfaces. Also watch for EDN's DSP-chip directory.

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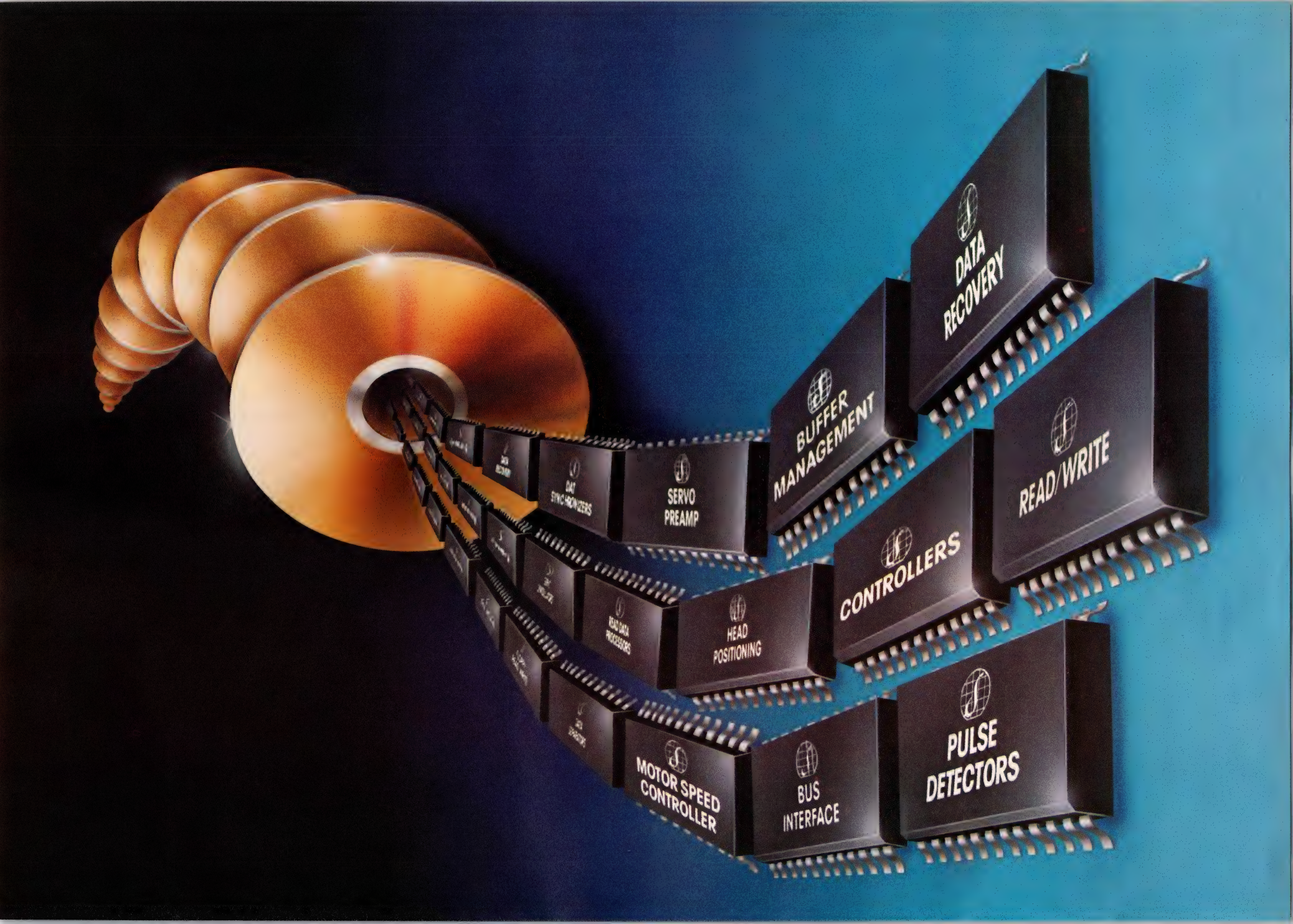
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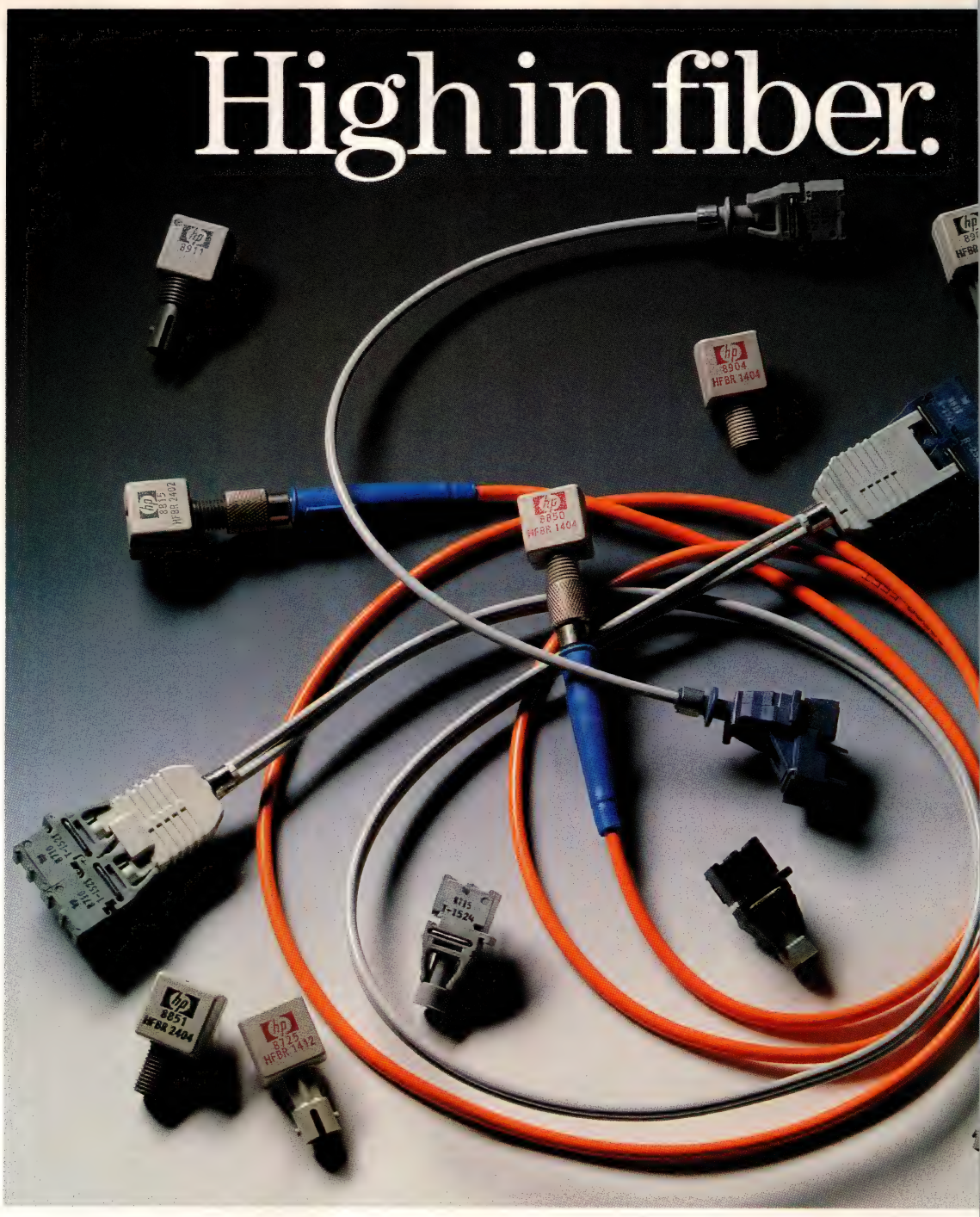

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FDDI ICs AND COMPONENTS

Reduced costs key FDDI's acceptance

The availability of VLSI FDDI ICs from several companies, and the standardization of components such as optical data links, will soon lead to reasonably priced FDDI implementations and, consequently, widespread use of the 100M-bps network.

Maury Wright,
Regional Editor

The FDDI (Fiber Distributed Data Interface) standard offers the performance potential to serve the network needs of systems ranging from PCs to mainframes. The LAN's key features include a 100M-bps data rate and fault-tolerance features not previously found in networks. The cost of implementing FDDI, however, has limited its viability, even in mainframe applications, until now. Over the next six months, emerging standard multisourced FDDI components and new VLSI ICs promise to make the fiber-optic-based network economically feasible in many applications.

FDDI networks potentially offer more than an order-of-magnitude increase in network bandwidth compared to Ethernet, the prevailing de facto standard. Ethernet networks transfer data at a maximum rate of 10M bps. In addition, the collision-detection scheme used by Ethernet results in serious bandwidth degradation as the number of nodes on a network increases.

Other key features of the FDDI standard include:

- 2-km maximum cable length between nodes (Ethernet's maximum length is 500m)
- 100-km maximum circumference of the physical ring (Ethernet's is 2.5 km)
- 500 nodes maximum
- fault-tolerant ability to self-heal after cable breaks or node malfunctions. (For more information on the FDDI standards, see **box,** "The FDDI specification.")

The FDDI standards define a token-ring network topology that ensures a 100M-bps data rate on transfers. Only overhead due to network transport protocols currently stops FDDI implementations from reaching the performance potential the standard offers.

Implementing an FDDI network also has more subtle positive and negative ramifications compared with other popular networks. The fiber-optic-based

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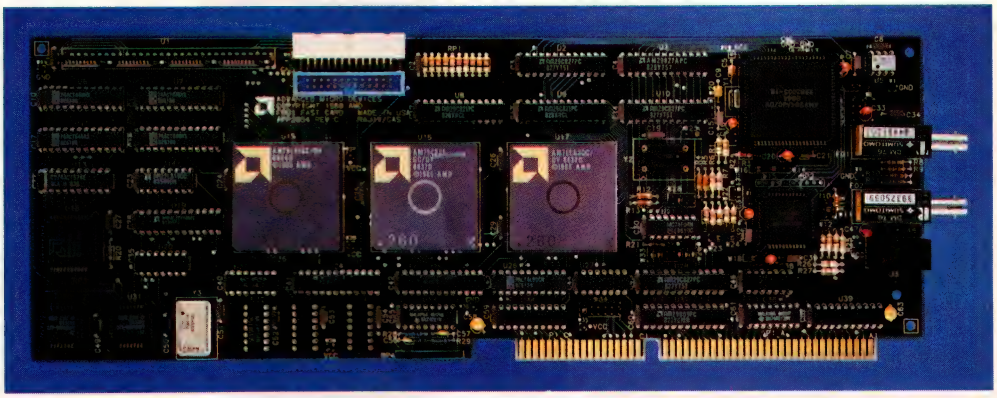

An evaluation and software-development tool, *the Fastcard IBM PC/AT-compatible FDDI board from AMD costs $6000 and employs the company's Supernet FDDI chip set.*

The FDDI specification

The fiber-optic-based LAN standard called FDDI supports a 100M-bps data rate and can connect as many as 500 nodes. Under development by ANSI subcommittee X3T9.5, the new network employs a token-ring topology and includes a number of fault-tolerant operational features not found in other networks. The ANSI committee has finalized the portions of the spec that define physical data transfers but is still working on a station-management standard.

FDDI is defined by four separate standard documents—the PMD (Physical Media Dependent) standard, the PHY (Physical Protocol) standard, the MAC (Media Access Control) standard, and the SMT (Station Management) standard.

The PMD specification defines the FDDI optical cable, transmitters, receivers, and connectors. The PHY standard specifies the clock rate, the data-encoding scheme, and an elasticity buffer that maintains network synchronization. Allocation of network bandwidth and the time-token protocol are defined by the MAC standard. The PMD, PHY, and MAC standards fit the seven-layer ISO (International Standards Organization) OSI model. The PHY and PMD combine to form Layer 1—the Physical Layer. The Data Link Layer (Layer 2) can be served by a Link Layer Control sublayer combined on top of the FDDI MAC standard.

The SMT standard introduces a new concept not found in the OSI model. Capabilities defined by the SMT standard include coordination of PMD, PHY, and MAC activity within a node, network bandwidth allocation, fault-isolation methods, and management of neighboring physical links in the network. To illustrate, envision SMT functions as adjacent to the OSI Physical and Data Link Layers and outside the actual OSI model. The FDDI committee has not completed the SMT standard.

The combination of the four FDDI standards results in a network based on a 125-MHz clock and 4B/5B group-encoding scheme that yields the 100M-bps data rate. The token-ring network can connect as many as 500 nodes with 2-km maximum cable length between nodes, and a maximum-ring circumference of 100 km. Like other networks, FDDI networks transfer data in packets. FDDI packets can range in size from 128 to 4500 bytes.

FDDI employs a counter-rotating dual-ring topology (**Fig A**). An FDDI network can include Class A nodes that attach to both rings, Class B nodes that attach to a single ring, and concentrators that connect Class B nodes to Class A nodes in a fault-tolerant manner.

The FDDI concept provides high performance and three levels of fault tolerance. Consider the scenario depicted in **Fig B**. The dual-ring network provides a recovery mechanism for cable breaks. Class A nodes perform an operation called a "wrap" to self-heal the ring. A wrap can also heal the ring in the case of failure or power down in a single node. Likewise, a concentrator can bypass Class B nodes in the case of cable breaks or even power down of a node. The concentrator can provide a convenient way to connect personal computers or workstations (that are often powered up or down) to an FDDI network of larger computers. The FDDI

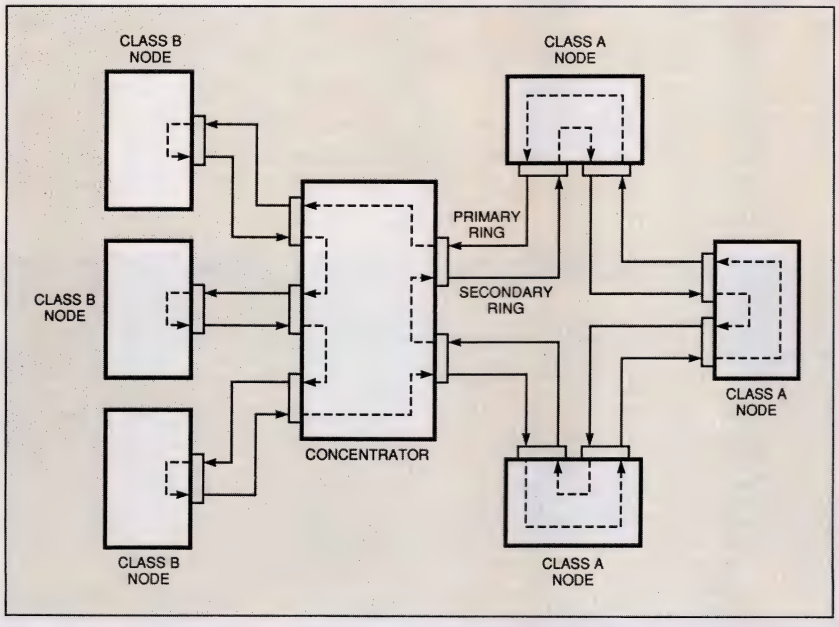

Fig A—A counter-rotating dual-ring topology *allows flexibility in implementing FDDI networks for systems ranging from personal computers to mainframes.*

standards also define an optical bypass to help ensure fault tolerance. A node that includes the optical-bypass feature simply passes the fiber-optic signal along when the node is inactive.

FDDI's 100M-bps data rate supports the performance needs of most LAN applications. The FDDI standards do not, however, prevent you from using both rings to double network bandwidth when no faults exist on the network. Class A nodes can include the capability of communicating on both rings simultaneously. The second ring can also be used to monitor network operations or perform diagnostics.

Although FDDI standards leave many decisions to the implementor, all FDDI networks employ the same token-passing communication scheme. That is, a logical token passes around the physical FDDI ring. Each node can only use the network to transfer data when it holds the token. A FDDI network goes through a "claim" process at start up. During the claim process each node "bids" via "claim frames" on network parameters such as the THT (Token Holding Time)—the amount of time any node can hold the token—and the TRT (Token Rotation Time)—the time required for a token to pass completely around the ring. The lowest bidder establishes the network parameters during the claim process.

During normal operations, each node is guaranteed that the time between token accesses will be less than 2×TRT. A delay of greater than 2×TRT causes the network to restart the claim process. A broken cable or other fault will cause the claim to fail. Upon claim failure, the network performs a "beacon" process, resulting in wraps at the proper nodes. The network then re-enters the claim and completes the healing process.

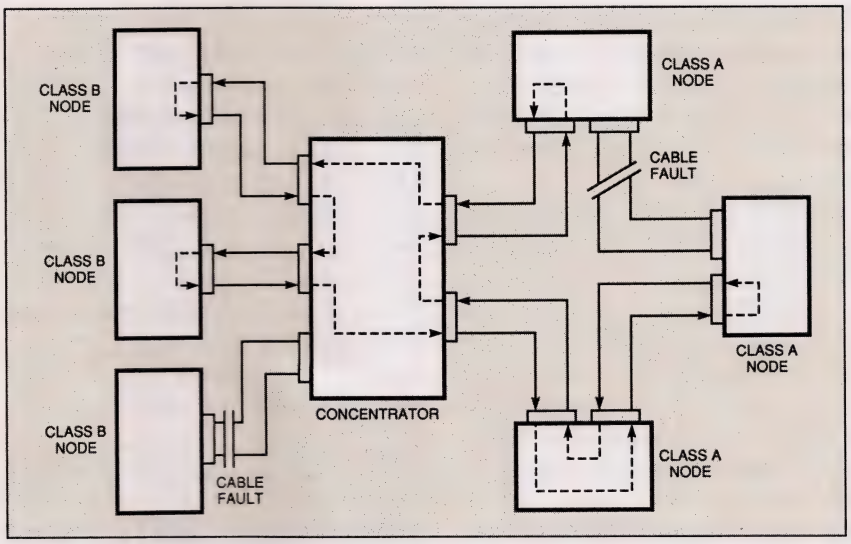

Fig B—Concentrators and wrap capability *defined in the standard allow FDDI networks to heal themselves after cable breaks or node malfunctions.*

The FDDI standards define both synchronous and asynchronous types of transfers. The total network bandwidth is divided among the nodes and therefore each node is guaranteed a certain amount of synchronous bandwidth. If a node doesn't need its full THT allotment, it can release a token early. System managers must ensure that applications requiring regular service use synchronous transmission service. For example, communications in real-time systems can use synchronous service. Potentially, synchronous transmissions can also carry voice messages using the guaranteed bandwidth.

Because of the limited synchronous bandwidth, however, a system implementation typically has to limit the amount of applications that use the synchronous service. Nodes can perform asynchronous transmissions in the excess bandwidth created when other nodes don't use all of the alloted synchronous bandwidth—the excess bandwidth created when nodes release the token early. In fact, typical implementations will result in a high percentage of network usage being asynchronous.

The standards also permit implementations whereby a defined group of nodes instigates a mode of operation that restricts the use of the token to specific nodes. The restricted operations allow high-priority applications, for example emergency shut-down procedures, to have essentially private use of the network.

You can obtain individual copies of the FDDI specifications (and all ANSI specifications) from Global Engineering (Irvine, CA (800) 854-7179).

FDDI network eliminates EMI and RFI concerns common to any network based on conductive cable. Furthermore, the FDDI network offers better security—the fiber-optic medium makes snooping on network transmissions much more difficult than on networks based on conductive cable.

However, you can't bus fiber optics together. Therefore, each node must receive all data transmissions that circulate around the ring, and then retransmit (referred to as repeat) any transmissions addressed to other nodes. In fact, because fiber optics must be connected point-to-point, token ring is the only network topology that truly makes sense for a fiber-optic-based network.

Because each FDDI node includes separate receive and transmit circuits, connectors, and optical data links, implementing an FDDI node can be more complex than implementing other network nodes. Furthermore, the FDDI standard defines a second ring to achieve fault tolerance; this second ring requires another receive/transmit facility. But the repeat operation performed at each FDDI node also offers benefits. Each node decodes, checks, recodes, and reclocks data. Therefore, FDDI networks, in addition to supporting much longer cable lengths between nodes, offer better error specs than a network such as Ethernet.

FDDI networks suit a number of applications. For example, the performance specs would allow the network to serve a corporation or university campus that might physically be the size of a small town. In fact, the term LAN doesn't accurately describe the FDDI network's capabilities, because the network can exceed the bounds of what most people think of as local. FDDI networks even exceed the performance wide-area networks offer, but they don't cover as wide an area (wide-area networks can connect computers worldwide).

FDDI can serve as a backbone

You can also expect to see FDDI networks used as backbones to connect many slower departmental Ethernet networks. Furthermore, most industry analysts believe that the cost of using an FDDI network will eventually drop to a level in line to meet the budget constraints of PC and workstation networks.

The key to lower-priced FDDI networks lies primarily in two product areas. First, FDDI implementations require a complex interface to perform the repeat functions and fast data transfers inherent in the network. Therefore, VLSI FDDI ICs are a necessity for reasonably priced FDDI implementations that perform according to the spec. Second, the price of components that provide the electronic-to-optical interface must decrease.

More chips to come soon

Consider the VLSI IC issue. Currently only Advanced Micro Devices offers a complete VLSI chip

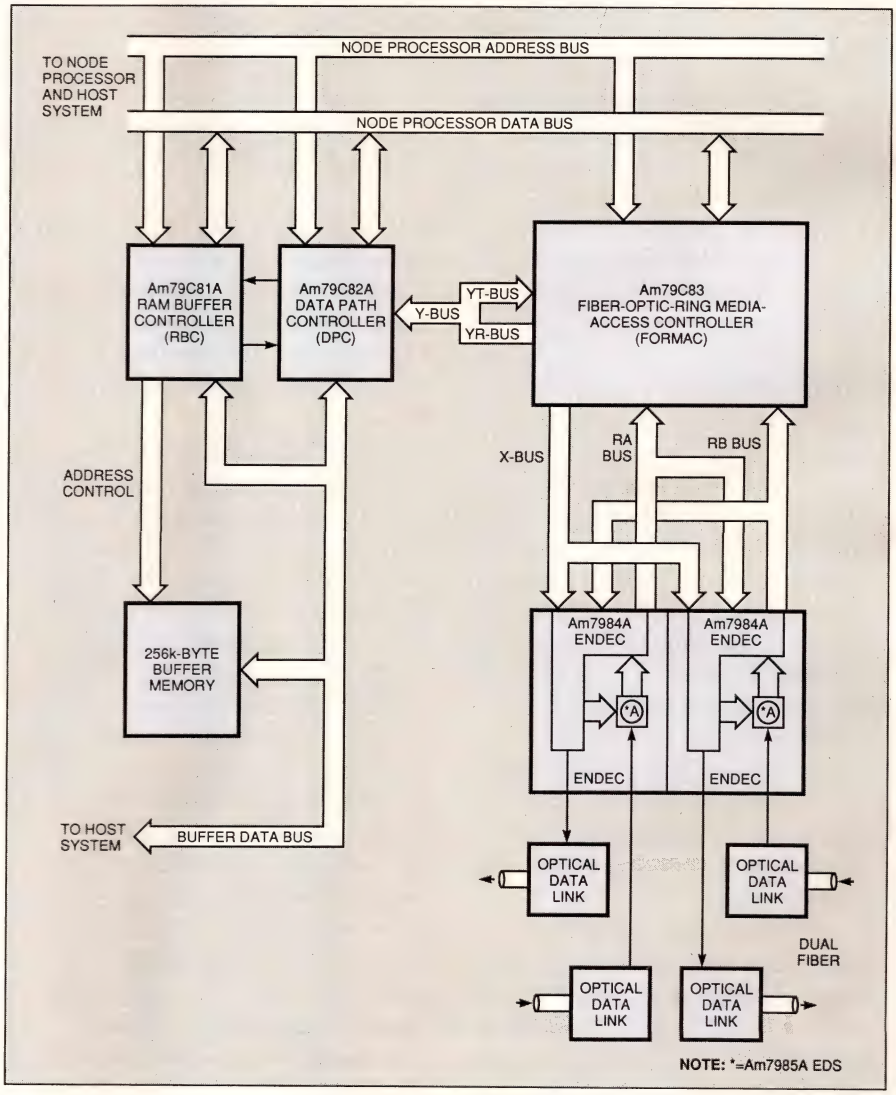

Fig 1—A local-node processor and buffer memory *combine with American Micro Devices' Supernet chip set to implement an FDDI node.*

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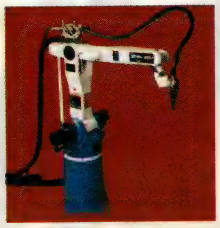
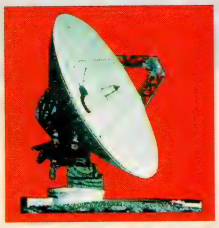


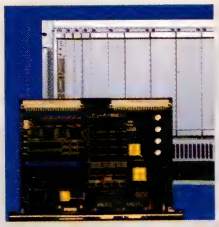

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FDDI ICs and components

set that you can use to implement FDDI networks. You can, however, expect other major chip manufacturers, such as AT&T, Intel (Chandler, AZ), and National Semiconductor (Santa Clara, CA), to introduce competing chip sets within a year.

Advanced Micro Devices' Supernet chip set includes five ICs which, along with a controlling μP, buffer memory, and electro-optical interface, allow you to build an FDDI node. The chip set includes the Am79C81A RAM Buffer Controller (RBC), the Am79C82A Data Path Controller, the Am79C83 Fiber Optic Ring Media Access Controller (FORMAC), the Am7984A Encoder Decoder (ENDEC), and the Am7985A ENDEC Data Separator (EDS). **Fig 1** depicts the chip set in an FDDI node. Note that an FDDI implementation that provides Class A or dual-ring access requires two ENDECs and two EDS ICs.

The RBC IC includes three DMA channels that allow a local FDDI node processor, a host bus, and the FDDI interface access to a 32-bit-wide RAM buffer. The buffer stores frames received from the network and frames waiting to be transmitted. The DPC interfaces the RBC and buffer to the FORMAC IC; it also converts 8-bit operations on the FORMAC side to and from the 32-bit buffer operations.

IC handles MAC layer

The FORMAC IC provides the Media Access Control (MAC) layer protocol defined by the FDDI standard. For example, the FORMAC includes the logic for token handling, address recognition, and CRCs (cyclic redundancy checks). The IC also processes data frames and determines network availability.

The ENDEC chip performs the 4B/5B encoding and decoding defined by the FDDI standards. The IC communicates with the FORMAC IC via an 8-bit bus and with the FDDI network via a serial NRZI (nonreturn to zero, invert on ones) data stream. The EDS extracts the clock signal from incoming NRZI data.

The company offers the 5-chip set for $625 (100). It also offers a $6000 IBM PC/AT-compatible board, called Fastcard, which uses the chip set and which also can be used as an evaluation tool, a software-development platform, or to test the operability of other FDDI designs.

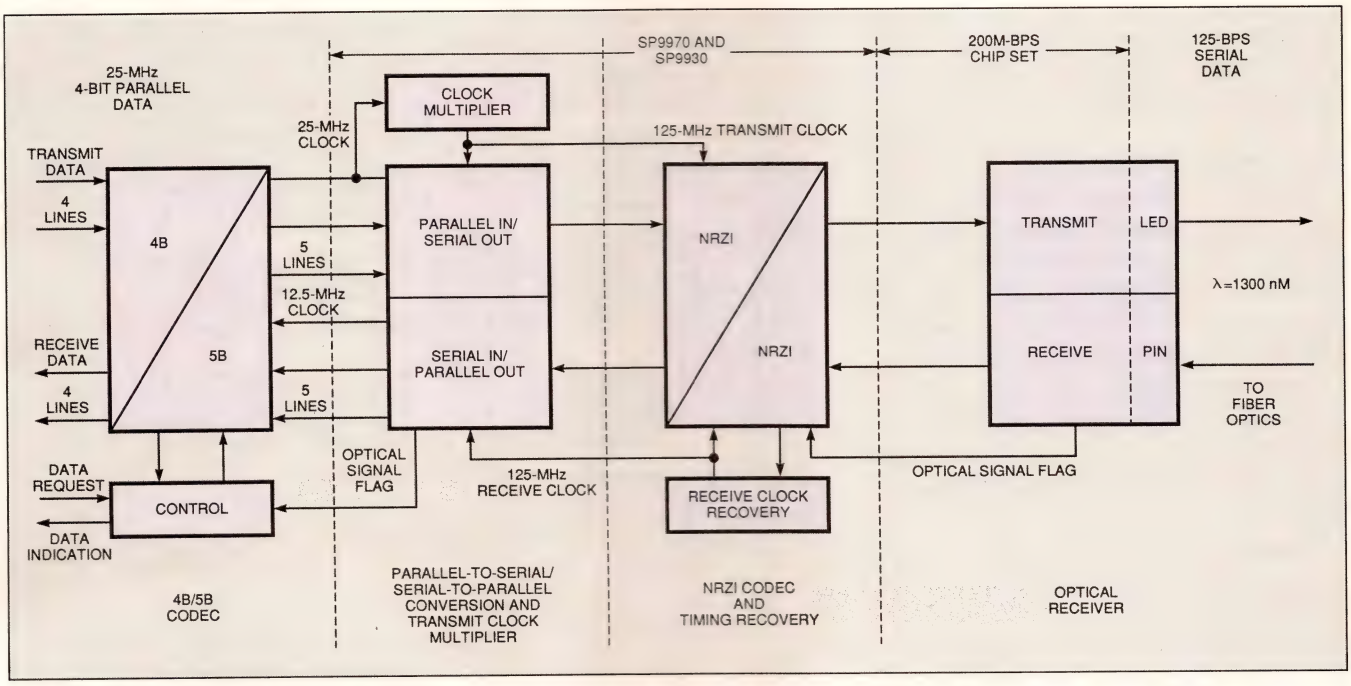

Fig 2—The PMD and PHY FDDI specs *define the lower layers of the network standard. The figure shows how Plessey ICs fit into a typical FDDI implementation.*

FDDI ICs and components

The price includes a number of software packages that support the applications listed above.

Chips encode/decode NRZI

Currently, Plessey Semiconductors is the only other company that has made ICs specifically for FDDI networks. Its SP9970 provides an interface between a 4B/5B encoder and the NRZI output; its SP9930 provides the opposite function for incoming data. The pair costs $150 (100). **Fig 2** shows how the Plessey ICs fit into an FDDI implementation.

The company also offers ICs that you can use in the electro-optical interface. For example, the SP9954 transmitter/driver, the SL9904 transimpedance amplifier, and the SP9944 regenerator provide the receive-and-transmit interface be-

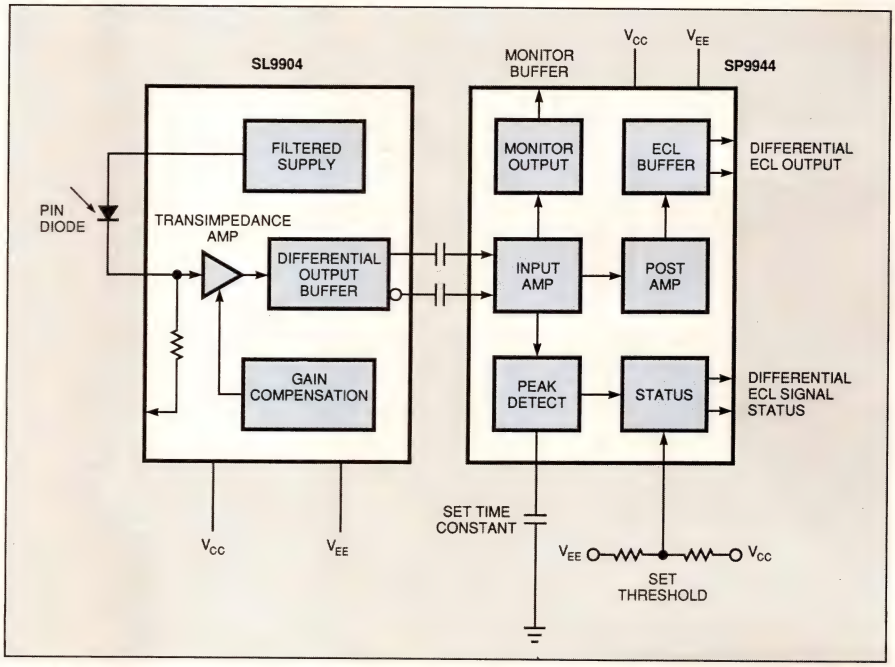

Fig 3—A transimpedance amplifier and regenerator IC from Plessey, the SL9904 and the SP9944, respectively, *take input from a PIN diode and generate an ECL NRZI data stream for data coming into a node from the FDDI network.*

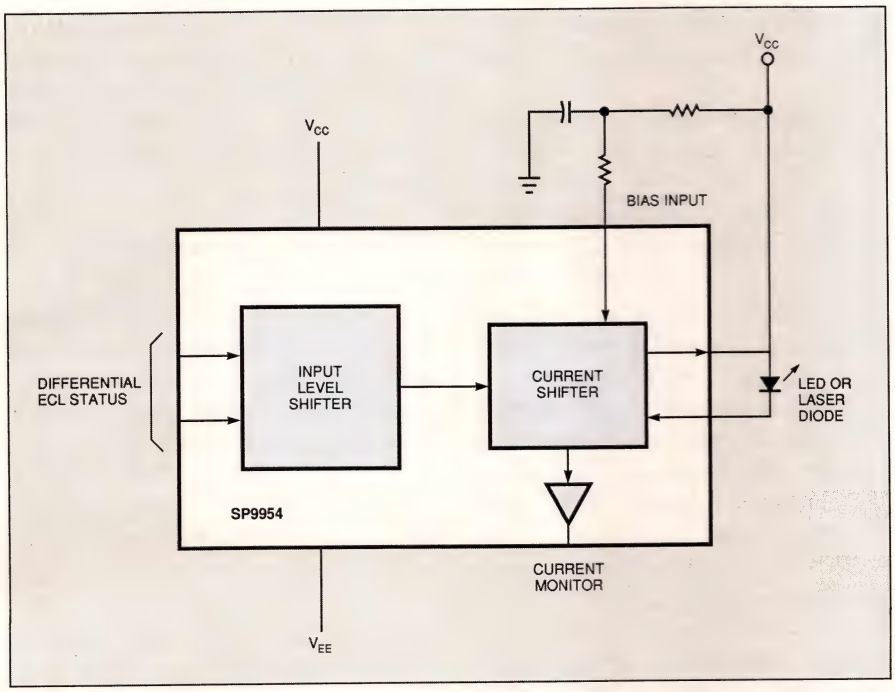

Fig 4—The SP9954 transmitter/driver circuit *from Plessey can drive signals onto the FDDI network with an LED or laser diode.*

tween optical components and NRZI data (**Figs 3** and **4**). The ICs cost $53.74 (1000) for a 3-chip set. The company calls the set the 200M-bit/sec Chip Set because, as the name says, the parts can operate as fast as 200M bps.

Optical transceivers add cost

The electro-optical interface issue can most easily be resolved by optical data link modules, also called optical transceivers. Previously, implementing proprietary optical transceivers has cost companies that manufacture FDDI products as much as $2000 to $3000 per dual-ring connection.

Two recent agreements involving several major companies, however, should reduce that price per connection by an order of magnitude in the next year. First, AT&T and

PCO agreed to standardize and manufacture three optical data-link products, including a 125M-bps transceiver in a pc-board-mountable package with 32 pins divided into four rows. The agreement also defines 125M- and 200M-bps 16-pin transceivers that don't use the standard FDDI connector. But, the products can be used in applications that require the FDDI connector to be mounted on a bulkhead, away from the interface pc board.

Expect standard optical links

The other recent agreement involves AT&T, Hewlett-Packard, and Siemens. The three companies designed a transceiver that includes the standard FDDI connector, operates at full FDDI speeds, and is pc-board mountable. All three companies plan to manufacture the transceiver, which measures 3.75× 1.4 in. and has two rows of 11 pins each.

Transceivers resulting from these agreements should be available later this fall. The agreements should quickly increase the manufacturing volumes of FDDI components, and therefore reduce prices. Furthermore, the competition that multisourcing creates should result in further price reductions.

One final obstacle to the potential of FDDI networks involves transport-protocol software. The TCP/IP (Transmission Control Protocol/Internet Protocol) transport protocol is currently the dominant choice in heterogeneous networks. But TCP/IP adds substantial overhead to network operations. Typical installations of TCP/IP on 10M-bps Ethernet LANs only yield a throughput of 2M or 3M bps from application program to application program. The Open Systems Interconnection (OSI) TP4 transport protocol doesn't promise big improvements either.

TCP/IP slows FDDI operation

Expect most early FDDI implementations to use the TCP/IP protocol because of its widespread use and popularity. FDDI-board manufacturers will simply try to minimize overhead by using more powerful local μPs on the network boards. American Micro Devices recommends its 29000 reduced-instruction-set computer μP as a companion to its FDDI chip set, for example. In the future, new, radically different transport protocols that can readily be implemented directly in silicon may solve the overhead

problem.

Work has also begun on extensions to FDDI and possibly a FDDI II set of specs before FDDI is fully defined and in widespread use. In the near future you can expect definitions of fiber-optic-based networks that operate as fast as 250M or even 500M bps. Furthermore, the maximum length of cable that can connect nodes may reach 50 km or more. Finally, you can expect hybrid networks that will support packet-switching networks, such as today's FDDI and circuit-switching networks for voice transmission. FDDI II may provide all the capabilities that ISDN promises but with data transfers that are orders of magnitude faster. EDN

Article Interest Quotient (Circle One)
High 473 Medium 474 Low 475

For more information . . .

For more information on the FDDI products discussed in this article, circle the appropriate numbers on the Information Retrieval Service card or use EDN's Express Request service. When you contact any of the following manufacturers directly, please let them know you saw their products in EDN.

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Advanced Micro Devices Inc
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PCO Inc
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	Output Power	Output Voltage (V) Current (A)
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AHE2812S	20	12V, 0 - 1.67A
AHE2812D	15	±12V, 0 - 625mA
AHE2815S	20	15V, 0 - 1.33A
AHE2815D	15	±15V, 0 - 500mA

-55°C to +85°C and -55°C to +125°C
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CIRCLE NO 69

EDN's Industrial Electronics Product Showcase

Today's industrial systems and controls feature user-friendly interfaces

EDN's Industrial Electronics Product Showcase focuses on system-level industrial products and components specifically designed for use in systems intended for harsh industrial environments. You'll note that today's system-level products offer high performance and also feature very user-friendly interfaces.

For example, Burr-Brown's PCI-501H workstation lets you collect data and control tests within 30 minutes after receiving it. Its menu-driven, factory-installed software enables you to communicate with the system without having to become a programmer. The μDCS-6000 μP-based control system from Analog Devices also eliminates the need for programming expertise. You simply employ menu-driven control blocks containing prearranged algorithms to map I/O processes and associated events with defined parameters.

User-friendly interfaces are also key features of the latest control components. The Temp-200 from Acculex is a full-featured, field-programmable temperature controller that provides you with a menu-selectable choice of inputs. Using the sealed keyboard, you can select one of 17 functions by cycling through the menu. The Pixie module from IEE Inc is another component that's designed to simply the man/machine interface. It integrates a low-power LCD and custom IC driver into the keycap of an spst momentary contact switch. You can configure the module to provide full-screen graphics displays or 3-line × 6-character alphanumeric presentations.

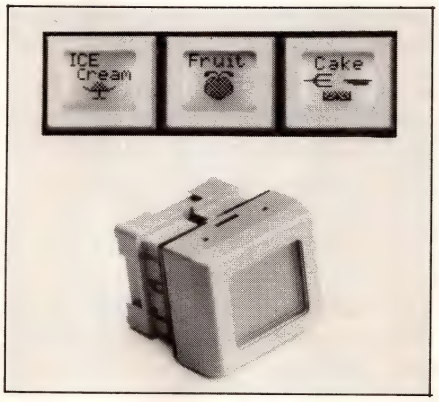
Many of today's industrial systems bring the power of the computer to the factory floor. Fluke's 1034 Scantouch terminal uses touchscreen technology to provide the operator interface. The terminal interprets commands from the host computer to create displays that provide information for the operator, or prompts the operator to make a selection from the choices presented. The Model 1448 PC-bus factory workstation from Texas Microsystems is housed in an enclosure that meets NEMA 4 requirements to the panel level, and meets industrial-quality standards throughout. It features a passive backplane architecture, speeds to 20 MHz, and a 14-in. graphic display.

Since this showcase doesn't confine itself to just high-level systems, you'll find numerous examples of other equipment and components, including transducers, switches, oscilloscopes, power supplies, and displays, to name just a few. You may very well find just the product you've been looking for. EDN

Industrial Product Showcase

LCD/switch combination eases man-machine interface

The Pixie module is designed to simplify the man/machine interface. It integrates a low-power LCD and a custom IC driver into the keycap of an spst momentary contact switch to provide a user-friendly method for machine control and display applications. The LCD employs super-twist technology and features LED-type backlighting to accommodate low ambient lighting conditions.



The LCD consists of 864 pixels in a 24×36-pixel matrix that provides full-screen graphics displays. You can also configure the Pixie's display in a 5×7-dot matrix to obtain a 3-line $\times$ 6-character alphanumeric presentation. The total viewing area is 0.49×0.59 in.

The spst switch contacts have a nominal rating of 12V dc at 50 mA. The contact-withstanding voltage rating is 250V ac for 1 minute. Contact resistance and isolation resistance are 1Ω max and $50 \times 10^6\Omega$ min, respectively. Actuation force is $130g \pm 20g$; switch-bounce time is 5 msec max.

The $\frac{7}{8} \times \frac{3}{4}$-in. Pixie module, which costs $40.72 (100), is designed for through-the-panel pc-board mounting and requires a behind-the-panel depth of only $\frac{3}{4}$ in. Module life expectancy is at least 10^6 operations; the operating range spans 0 to 40°C.

IEE Inc, 7740 Lemona Ave, Van Nuys, CA 91409. Phone (818) 787-0311. FAX 818-902-3723.

Circle No 733

Smart process monitor/controller features two isolated signal inputs

The PM-5080 process monitor/controller features two isolated voltage/current signal inputs—0 to 100 mV (or 0 to 20 mA), and 0 to 10V. It also offers four programmable setpoint relays for on/off control, an RS-232C port, and an optional analog output for linear control applications. User-defined algorithms and input scaling functions allow you to adapt the unit to a variety of input/output tasks.

Input signals are easily scaled to engineering units for display on the PM-5080's 6-character fluorescent readout, which can also display any 2-character unit descriptor. You can also configure the readout to alternately display (at 2-second intervals) as many as eight system variables. The setpoint relays will switch 300V/100-mA loads. The optional 0 to 10V analog output is controlled proportionally by one of the two input signals or a user-defined math function.

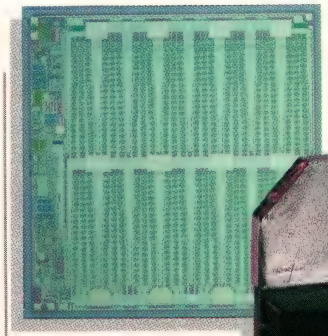
All configuration information can be entered using either the front-panel keypad or via commands sent through the serial port. When you're using the keypad, the menu and enter keys allow you to traverse a series of prompts, whichask you for specific operating parameters. With the serial port, simple ASCII commands read and set operating parameters.

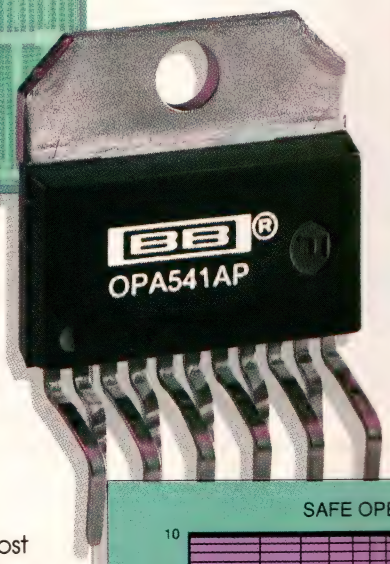
The $395 PM-5080 is housed in a $\frac{1}{8}$-DIN package, which also includes a choice of 100, 115, or 230V ac power supplies.

Datel Inc, 11 Cabot Blvd, Mansfield, MA 02048. Phone (508) 339-3000. FAX 508-339-6356.

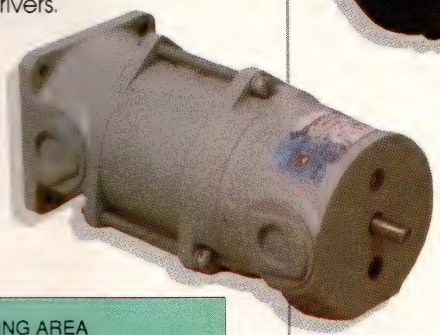
Circle No 734

A Little Buys a Lot of Power Op Amp



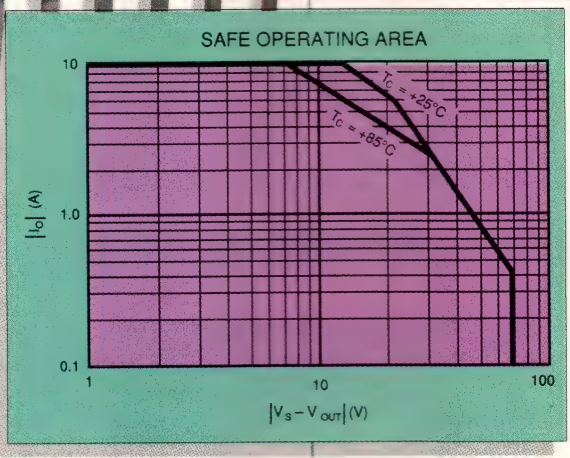


OPA541AP is the superior choice for a wide range of motor driver, servo amplifier, and programmable power supply applications; consider it also for audio systems and ATE pin drivers.



OPA541AP Delivers 5A at 30V

OPA541AP is the industry's first low cost power op amp. It's our popular monolithic IC, already proven in hundreds of applications, and now offered in a unique high-power plastic package. Not only does it take up less board space than a TO-3, but it's easier and cheaper to heat sink.



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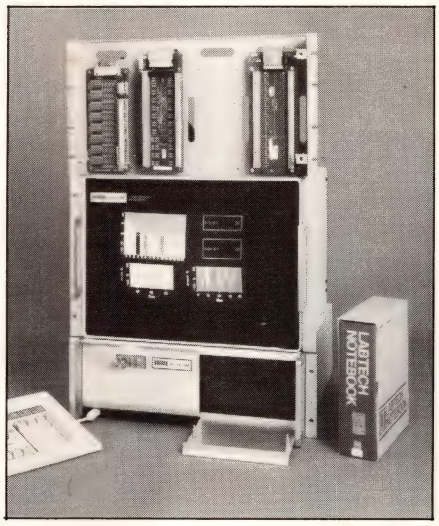
CIRCLE NO 70

Rugged, fully integrated workstation features user-friendly interface

Ease of use is a key feature of the PCI-501H Series workstation—a ready-to-run data-acquisition, test, measurement, and control system. Most users will be collecting data and controlling tests with the unit 30 minutes after setup.

The unit includes 48 single-ended analog-input channels (24 channels in differential mode), 32 channels of digital I/O, and 8 analog output channels. The workstation has 512k bytes of RAM, a 20M-byte hard disk, a 1.2M-byte floppy-disk drive, serial and parallel ports, a color graphics monitor, and a spill-proof keyboard.



The software to collect, store, control, and process data is factory-installed and menu-driven. The menus simplify the setting up of channel-numbering assignments, triggering, and real-time calculations. You can store acquired data onto disk and call up any setup for future runs.

The PCI-501H, which costs $11,995, is housed in a rack-mount enclosure. A 200W power supply and four expansion slots accommodate the need for future expansion. A complete set of termination panels and shielded/ground-plane cables, which make it easy to connect the workstation to input-signal sources and to output and/or control devices, is also included. Models are available for both 110 and 220V ac operation.

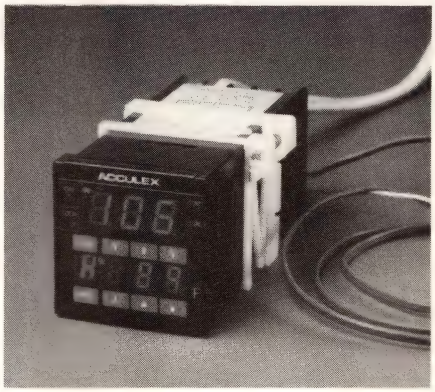
Burr-Brown, 1141 W Grant Rd, MS 131, Tucson, AZ 85705. Phone (602) 746-1111.

Circle No 735

µP-based temperature controller features automatic self-adjustment

The Temp-200 is a full-featured, field-programmable temperature controller that features a menu-selectable choice of inputs—J or K thermocouples, as well as 3-wire 100Ω platinum resistance-temperature detectors (RTDs). The unit features an automatic self-adjustment capability. You can also set up the controller from the front panel for proportional bandwidth, integral/reset time, derivative rate, cycle time, and on/off hysteresis readings.

Using the sealed-membrane keyboard, you can select one of 17 functions by cycling through the menu. Available functions include eight alarm-output modes, nine temperature ranges, a choice of °F or °C scales, a choice of input and output



control, temperature range, low/high and alarm limit. Resolution equals 1°C or °F for thermocouples and 0.1°C or °F for RTDs. All setup parameters are stored in nonvolatile RAM. In addition to the 2-line LED display, which shows both the current process variable and your choice of high or low set point, the Temp-200 features an alarm indicator and operational-mode indicator.

The main output control on the Temp-200 is a relay rated for 12V dc at 20 mA. A separate alarm relay is rated for 1A. Common-mode rejection is 120 dB min. The controller draws 8 VA and operates over a −10 to +55°C range.

The unit costs $327; it comes with an environmentally secure Mylar front panel. The linear-type menu features a mode display and increment/decrement choice selection. A front-panel lock prevents inadvertent setup changes.

Acculex, 440 Myles Standish Blvd, Taunton, MA 02780. Phone (508) 880-3660. TLX 503989.

Circle No 736

DAS 9200 Version 2

Now $18,000 will put the best on your bench: the DAS 9200.

The most impressive number to come out of the Tek DAS 9200 may be its price: now you can leverage the power of the DAS for little more than the cost of systems that aren't even in the same league. Consider:

32-bit MICRO SUPPORT

The smoothest, most elegant implementation for chips like the 80386, 68030 and 68020. The most sophisticated triggering of any logic analyzer ever built. Expand to monitor as many as six micros at once, with clock rates to 40 MHz.

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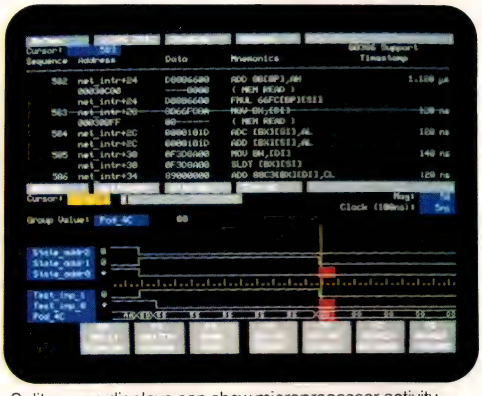

Split screen displays can show microprocessor activity time correlated with high-speed timing data (above) or disassembly of another microprocessor. The cursors can be locked to scroll in parallel, highlighting data nearest to the same point in time.

90 CHANNELS

Expand up to 540 acquisition channels or, using other modules, up to 160 channels at 2 GHz. Apply up to 1008 stimulus channels at 50 MHz.

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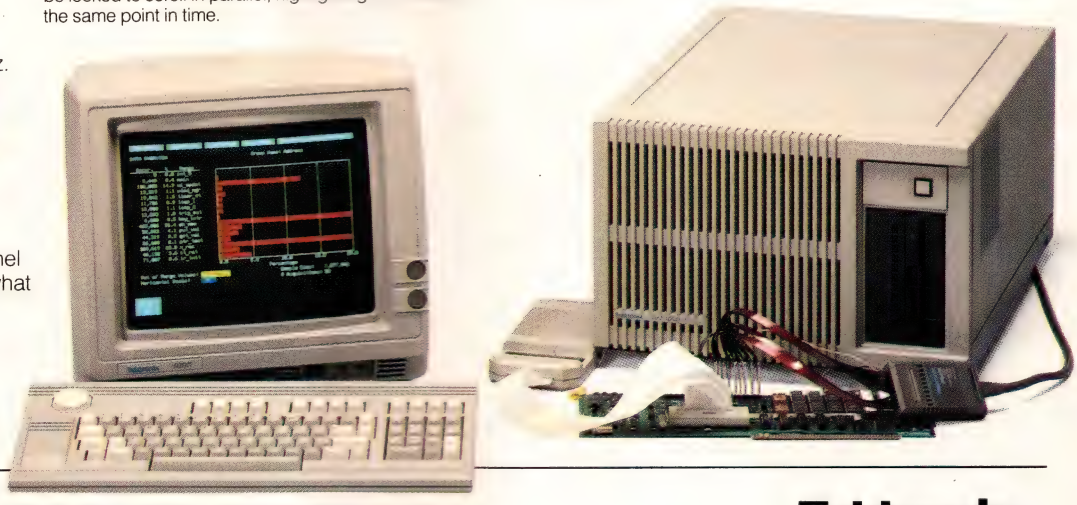

Tektronix
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Circle 5 for Literature

Circle 6 for Sales Contact

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Gates batteries have helped power Physio-Control medical products for more than a decade. That's because, at Gates, we believe in longterm relationships. So, whether you're developing a new product or trying to improve an existing one, we can help you like nobody else.

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The power that helped it get there.

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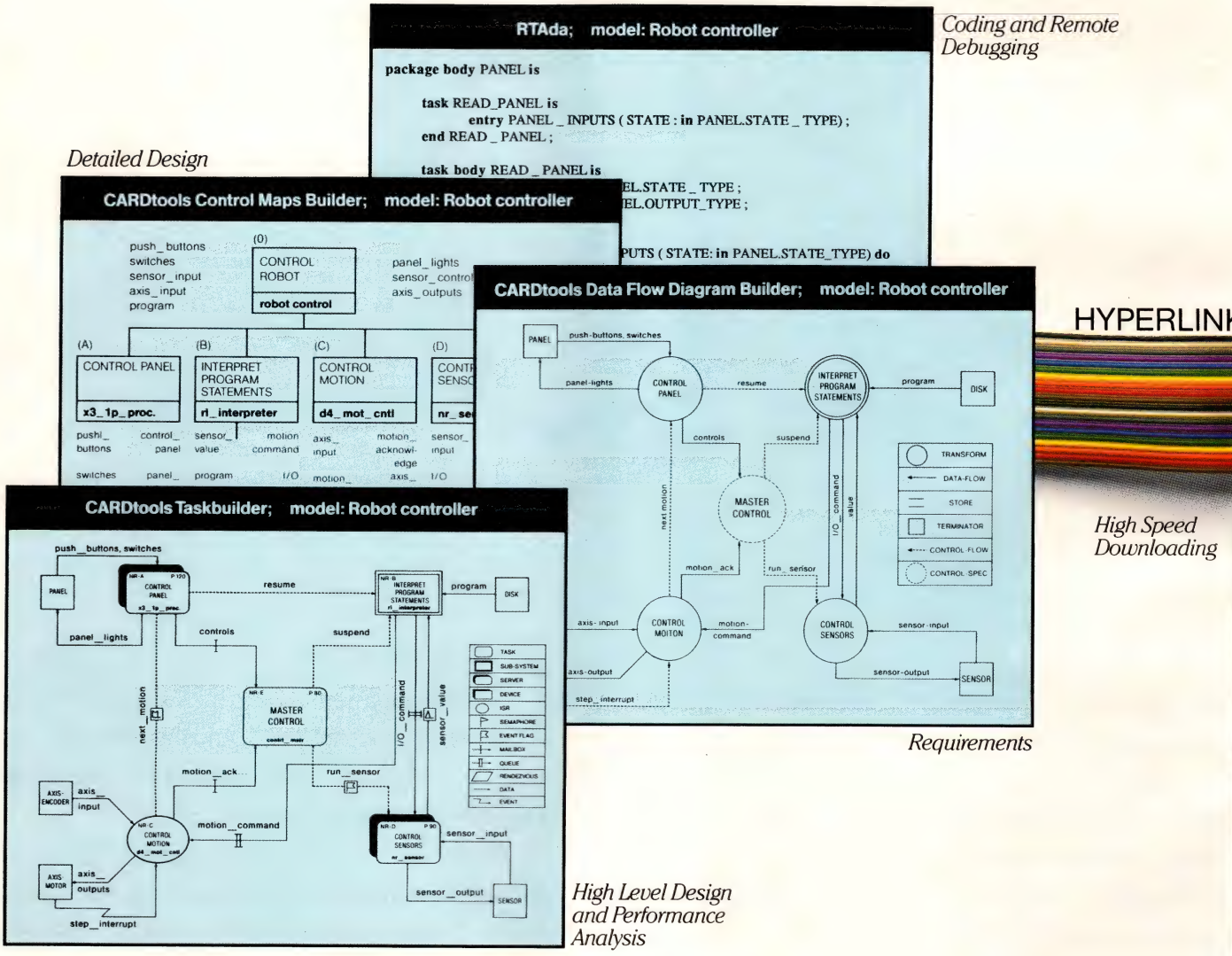
Do you have to design in



Coding and Remote Debugging

Detailed Design

HYPERLINK

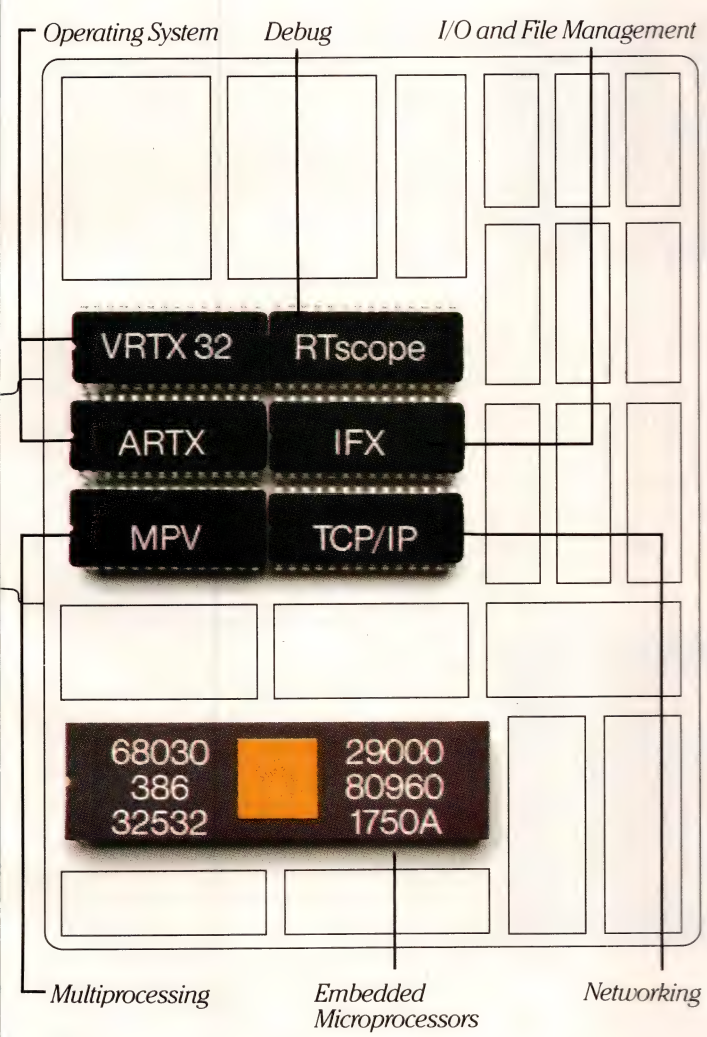
High Speed Downloading

Requirements

High Level Design and Performance Analysis

HOST

what it takes real-time?



TARGET

Successful real-time design for embedded systems takes more than extraordinary helpings of craft and creativity. It also takes the right tools. Which may explain why our CARD (Computer-aided Real-time Design) technology is behind the development of well over fifty million lines of real-time code.

We're not talking about ordinary tools spruced up with a few real-time extensions. CARD technology was created exclusively for the real-time world specifically for integrating run-time and software development environments.

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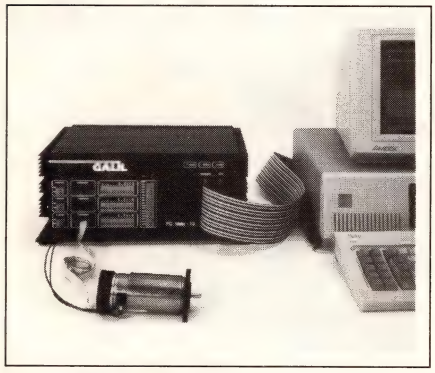
So if you'd like to have what it takes to make your next real-time project run more efficiently call us, toll free, at (800) 228-1249. Or (214) 661-9526 in Texas.

Because you can only be a success in real-time design if you've got the right stuff.

READY SYSTEMS

CIRCLE NO 72

Industrial Product Showcase



POWER AMPLIFIERS

The PC-Mate-10 Series power amplifiers consist of 1, 2, or 3 servo drivers and a power supply in a metal enclosure. To simplify motion-control system designs, the amplifiers can connect directly to servo motors and encoders.

A complete 3-axis system requires only an IBM PC/XT or PC/AT computer and an appropriate motion controller. The amplifiers' drivers are pulse-width-modulated at 30 kHz. The amplifiers are available with power ratings of 32V at 5A and 48V at 10A. When connected to an appropriate motor, the amplifiers achieve speeds of 4000 rpm and peak torques of 400 oz-in.

The amplifiers work from 110V ac power and operate over a 0 to 70°C temperature range. In 3-axis versions, the 32 and 48V amplifiers cost $1995 and $2595, respectively.

Galil Motion Control Inc, 1054 Elwell Ct, Palo Alto, CA 94303. Phone (415) 964-6494. FAX 415-964-0426.

Circle No 751

ACQUISITION UNIT

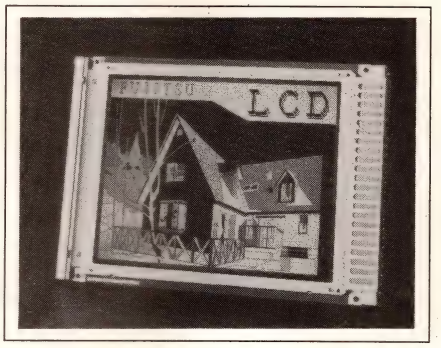
The Model 575 PC-based A/D data-acquisition instrument takes 50,000 measurements/sec. The vendor supplies two versions: the 575-1, which digitizes analog data with 12-bit resolution, and the 575-2, which provides 16-bit resolution.

Both units provide two outputs from high-speed D/A converters and allow you to connect eight differential or 16 single-ended analog inputs. They also provide 32 digital I/O channels. The connection scheme facilitates the use of Analog Devices' 3B Series analog signal conditioners.

The supplied software drivers permit you to control the instruments from programs written in advanced PC Basic (BasicA). An optional software package is compatible with several implementations of C and Pascal. 575-1, $1300; 575-2, $1600.

Keithley Instruments Inc, 28775 Aurora Rd, Cleveland, OH 44139. Phone (800) 552-1115; in OH, (216) 248-0400. TLX 985469.

Circle No 752



DISPLAY

Featuring cold cathode fluorescent sidelighting, the FLC640480WSUB black-and-white LCD uses double super-twisted-nematic technology. The display's polarizing layers consist of indium tin-oxide-coated glass substrates, which produce a high-refractive light coefficient.

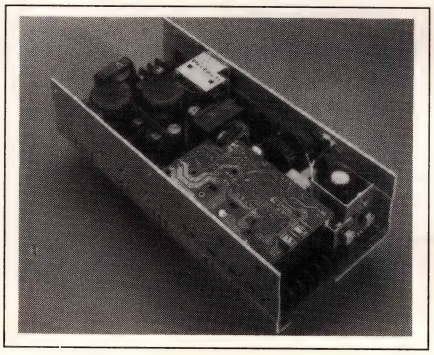
The display has a 640×480-dot matrix and features a 50° viewing angle cone. The unit has a 15:1 contrast ratio and a 15.12-fL brightness level. The display also has a 180-msec response time and a 8.3×6.2-in. viewing area. The overall panel measurements are 11.7×8 in. $575 (1000).

Fujitsu Component of America, 3330 Scott Blvd, Santa Clara, CA 95054. Phone (408) 562-1000.

Circle No 753

POWER SUPPLIES

The NFS350 Series open-frame switchers accept any input voltage from 85 to 264V ac without the need for jumper wires or a switch. The NFS350-7625 model has outputs of 5.1V, ±12V, and a floating output that you can adjust from 4.5 to 16.5V and reference as either positive or negative. A second model, the NFS350-7626, offers outputs of 5.1V, ±12V, and a floating output that you can adjust from 15 to 30V and reference as either positive or negative.



With forced-air cooling, total supply output power at an ambient temperature of 50°C is 350W. The supplies' typical efficiency is 70%. The NFS350 Series supplies are UL-, CSA-, and VDE-approved, and their built-in line filter reduces conducted noise below FCC limit B and VDE limit A. $319 (100).

Computer Products/Boschert, 3797 Spinnaker Ct, Fremont, CA 94538. Phone (415) 657-6700.

Circle No 754

Text continued on pg 104

Now, what about the other 95% of your design?

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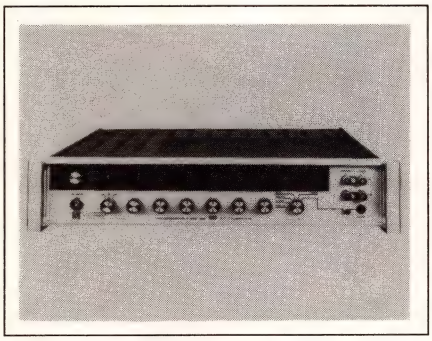


DC CALIBRATOR

The Model 521 is a μP-based, IEEE-488-controlled, dc voltage/current calibrator. It transparently runs programs written for the vendor's earlier Models 520, 520/A, and 501J.

The 3½-in.-high unit produces currents from 10 nA to 110 mA in two ranges, and voltage compliance in current-forcing mode is 100V. The instrument has three voltage-forcing ranges with 100-mA compliance. The 521 produces outputs from 100 nV to 100V and offers an optional 1100V range.

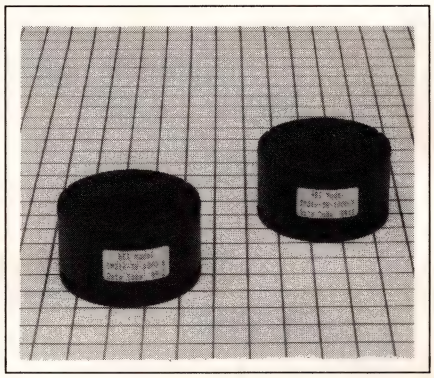
All instrument ranges provide 1-ppm resolution and a crowbar zero. Within one year of calibration, voltage-forcing error is 20 ppm; current-forcing error is 50 ppm. $3150. Delivery, 60 days ARO.

Electronic Development Corp, 11 Hamlin St, Boston, MA 02127. Phone (617) 268-9696.

Circle No 755

MODULAR ENCODER

Designed to work with 6-, 8-, or 12-pole brushless motors, the CM216 Comtrac modular encoder provides digital commutation pulses as well as quadrature outputs and index pulse. Simple installation is a key device feature. You simply press the unit onto the back of your brushless motor and align the commutation tracks with the poles of the motor.

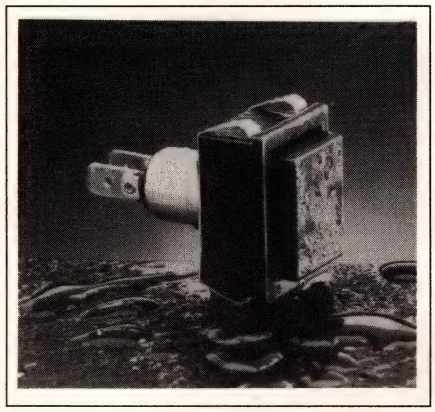


The CM216 effectively reduces the motor's length and cost by eliminating the need for extra commutation magnets. The encoder tracks on the encoder's code disk are not affected by hysteresis.

Housed in a 2.1-in.-diameter package, the CM216 accommodates motors featuring ¼-, ⅜-, or ½-in. throughshafts. An integral 360° servo groove simplifies the task of aligning the commutating tracks with the poles of the motor. The operating range spans 0 to 80°C. $97.50 (100).

BEI Motion Systems Co, 1755-B LaCosta Meadows Dr, San Marcos, CA 92069. Phone (619) 471-2600.

Circle No 756



SEALED SWITCHES

To accommodate harsh exterior environments, P3 Series rectangular-shaped pushbutton switches are completely sealed at both the front and back of the panel. Drain holes in the bezel allow water to exit and therefore prevent freeze-up during

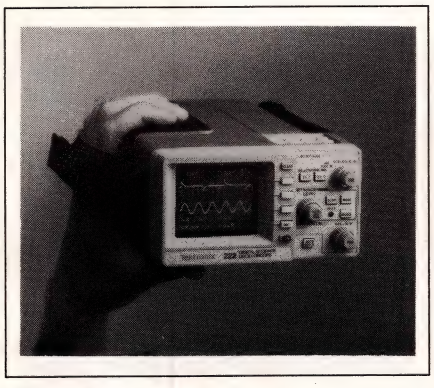
cold weather.

P3 Series snap-action switches are designed to handle loads from logic-level currents as high as 10A. The switches feature a contact-wipe design that helps break contact welds and maintain low contact resistance. Contact resistance is less than 25 mΩ.

P3 Series switches are designed to operate over a −55 to +85°C range. These snap-in mounted switches are available in NO, NC, and dpdt configurations. They have a 0.25-in. front-panel projection and a 1.125-in. rear-panel projection, including the 0.25-in. quick-connect terminals. $4.59 (100). Delivery, four to six weeks ARO.

Otto Controls, 2 E Main St, Carpentersville, IL 60110. Phone (312) 428-7171. FAX 312-428-1956.

Circle No 757



HANDHELD DSO

The 222 digital-storage oscilloscope has a 10-MHz bandwidth and is small enough to fit into your toolbox. It has a built-in battery, weighs just 4½ lbs, and measures 3½ × 6¼ × 10 in.

Each of the two y-axis inputs is ohmically isolated from the other and from the chassis. The 222 scope samples to 8-bit precision at 10M samples/sec; at fast sweep speeds, it automatically switches to equivalent-time sampling.

Despite its small size, the 222 incorporates many conveniences found in full-size digital-storage scopes—for example, storage and recall of control setups. An RS-232C port allows you to control the scope from a remote terminal or a computer and lets you unload captured waveforms. $2350.

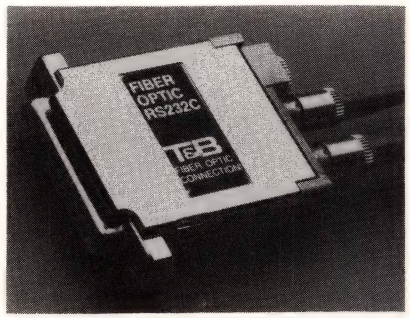
Tektronix Inc, Box 1700, Beaverton, OR 97075. Phone (800) 426-2200.

Circle No 758

RS-232C MODEM

These RS-232C modems link data-communication equipment to data-terminal equipment via fiber-optic cable. They accommodate either duplex plastic or glass fiber-optic cables and handle asynchronous data rates ranging to 19.2k baud.

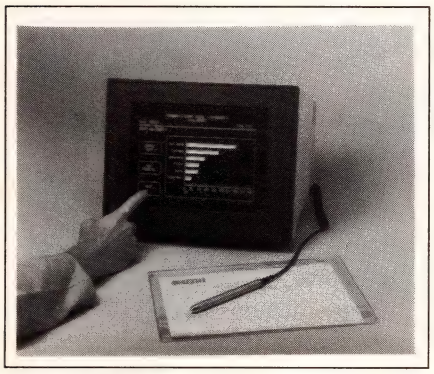
In addition to eliminating ground loops and EMI/RFI problems, the modems extend RS-232C transmission distances to as far as 2 km. Modem power is obtained through a DB25-pin connector or from an optional external plug-in-jack power supply. The units are available with either male of female contacts in data-communication- or data-terminal-equipment configurations. They are compatible with AT&T ST-type connectors. From $39 (100) Delivery, eight weeks ARO.



Thomas & Betts Corp, Electronics Div, 1001 Frontier Rd, Bridgewater, NJ 08807. Phone (201) 685-1600.

Circle No 759

Industrial Product Showcase



TERMINAL

The 1034 ScanTouch terminal uses touchscreen technology to provide the operator interface. It also features an integral bar-code reader, which accepts input from a variety of bar-code devices.

The terminal interprets commands from the host computer to create displays that provide information for the operator, or prompts the operator to make a selection from the choices presented. The 1034 can thus provide simple menu-type interaction with the operator for any number of functions.

The terminal connects to a host computer via RS-232C, RS-422, or RS-485 multidrop ports. In a multidrop configuartion, you can connect as many as 32 terminals to one serial-interface port. A bar-code wand and a NEMA 12 dust-tight, drip-proof panel-mount kit are optional. $2795. Delivery, 10 weeks ARO.

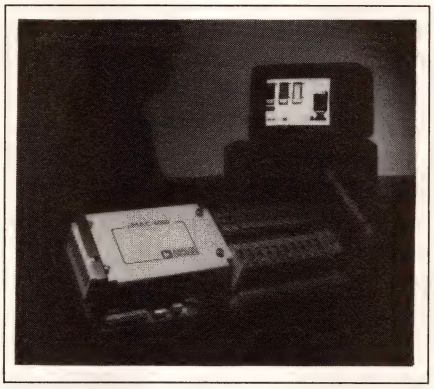
John Fluke Mfg Co Inc, Box C-9090, Everett, WA 98206. Phone (206) 347-6100. TWX (910) 445-2943.

Circle No 760

CONTROL SYSTEM

The μDCS-6000 μP-based control system eliminates the need for programming. Users simply employ menu-driven control blocks containing prearranged algorithms to map their I/O process and associated events with defined parameters.

The system operates under the direction of FIX DMACS proprietary software. Control blocks of FIX DMACS are embedded as firmware on the -6000 for complete, independent operation. The system features 256k bytes of battery-backed RAM and a 0.1-sec scan rate. The system readily accommodates modular I/O expansion. You can multidrop as many as eight controllers from a single host workstation. Each controller has 344 analog and digital I/O points; modular expansion boards allow you to increase I/O capability to 1376 points.



Four versions of the -6000 provide applications with a best-fit solution for a number of processes. The S version features SCADA (statistical control and data acquisition). SCADA and additional batch and continuous control are provided by the CN version. The CN87 adds number-crunching capability. The SPC87 model provides all of the above plus statistical process control and histogram capability. $3595 to $4995.

Analog Devices Inc, Box 9106, Norwood, MA 02062. Phone (617) 326-6666.

Circle No 761

SERVO AMPLIFIER

The Motomatic II single-axis, 4-quadrant PWM amplifier is designed to drive a variety of dc servo motors. The totally enclosed package's front panel features coarse and fine adjustments, as well as digital speed and torque readouts.

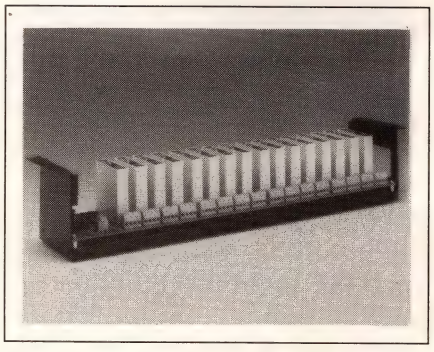
The amplifier's input power

range is 120 to 240V ac at 49 to 440 Hz. Peak and continuous output power ratings are 6 and 3A, respectively. From no-load to full-load conditions, the amplifier will hold motor-speed variations to within 1% of set speed.

Electrical specifications for the Motomatic II include a switching frequency of 25 kHz and an input impedance of 22 kΩ. Short-circuit and overload protection are standard. The operating range spans 0 to 50°C. $695.

Robbins & Myers/Electro-Craft, 6950 Washington Ave S, Eden Prairie, MN 55344. Phone (800) 328-3983.

Circle No 762



SIGNAL CONDITIONERS

SCM5B Series single-channel analog signal conditioners are specifically designed for harsh industrial control and measurement applications. The line includes two voltage-input modules (SCM5B30 and -31), a thermocouple-input module (SCM-5B17), and two wide-bandwidth voltage-input modules (SCM5B40 and -41).

Text continued on pg 111

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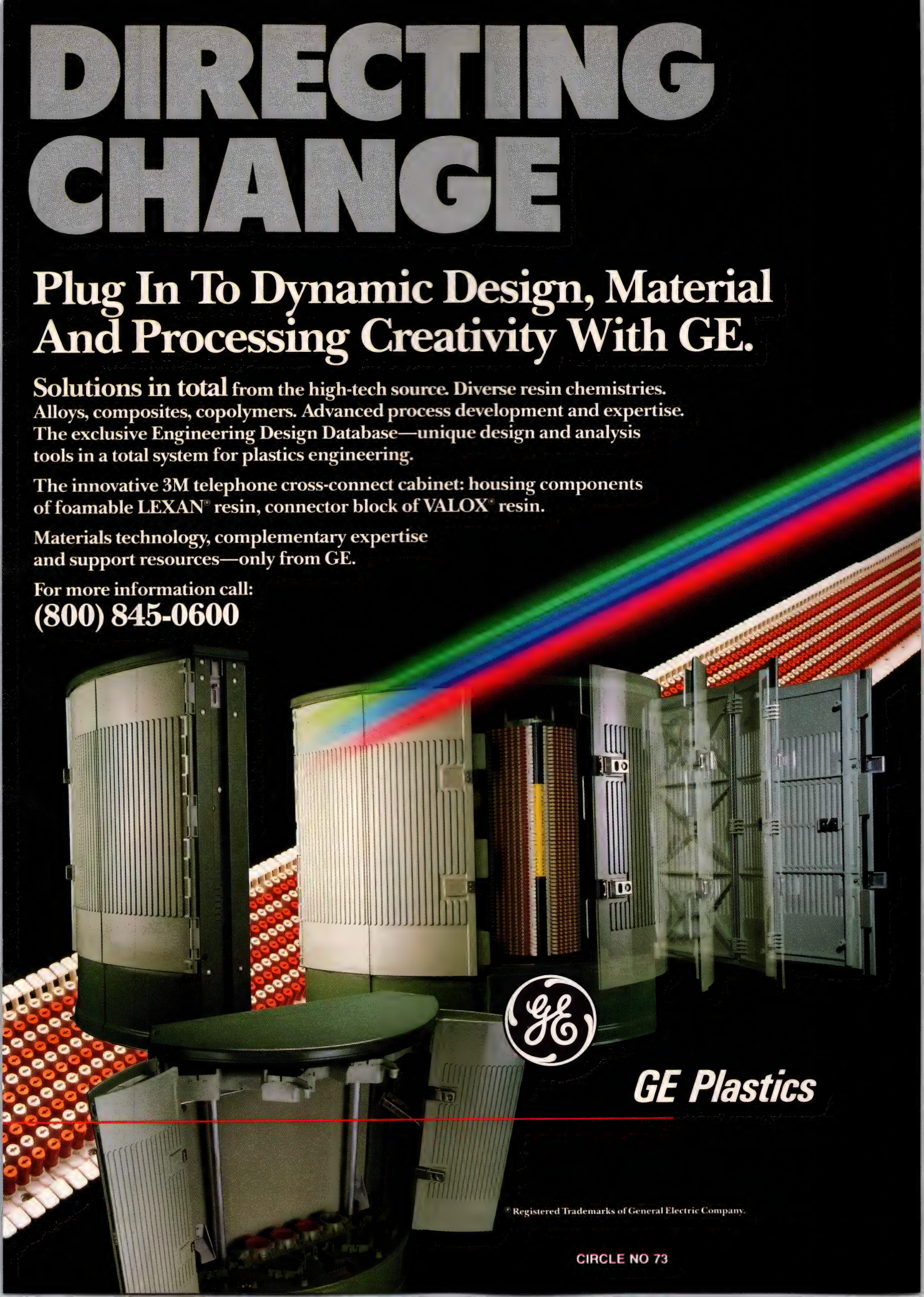

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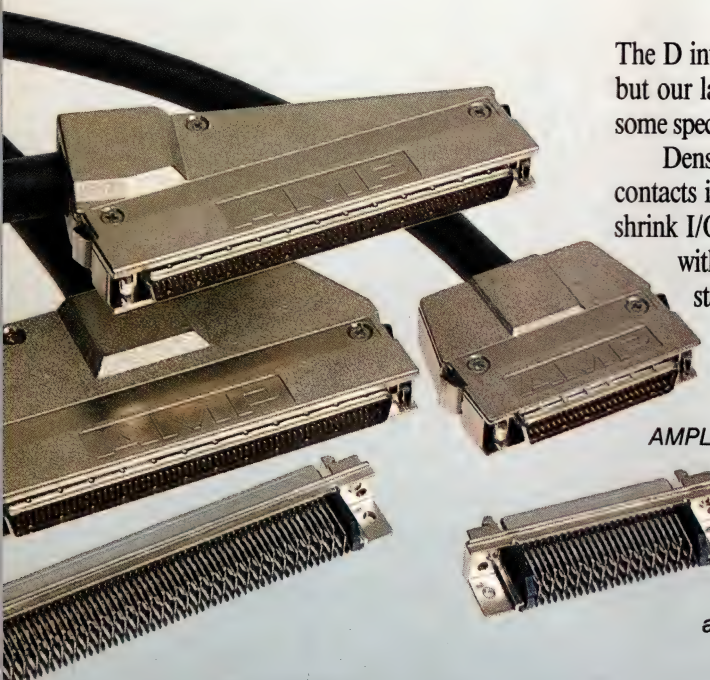
CIRCLE NO 73

.050 centerline shielded I/O.

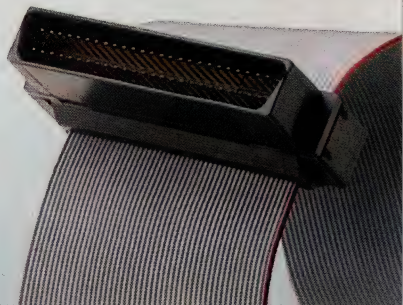


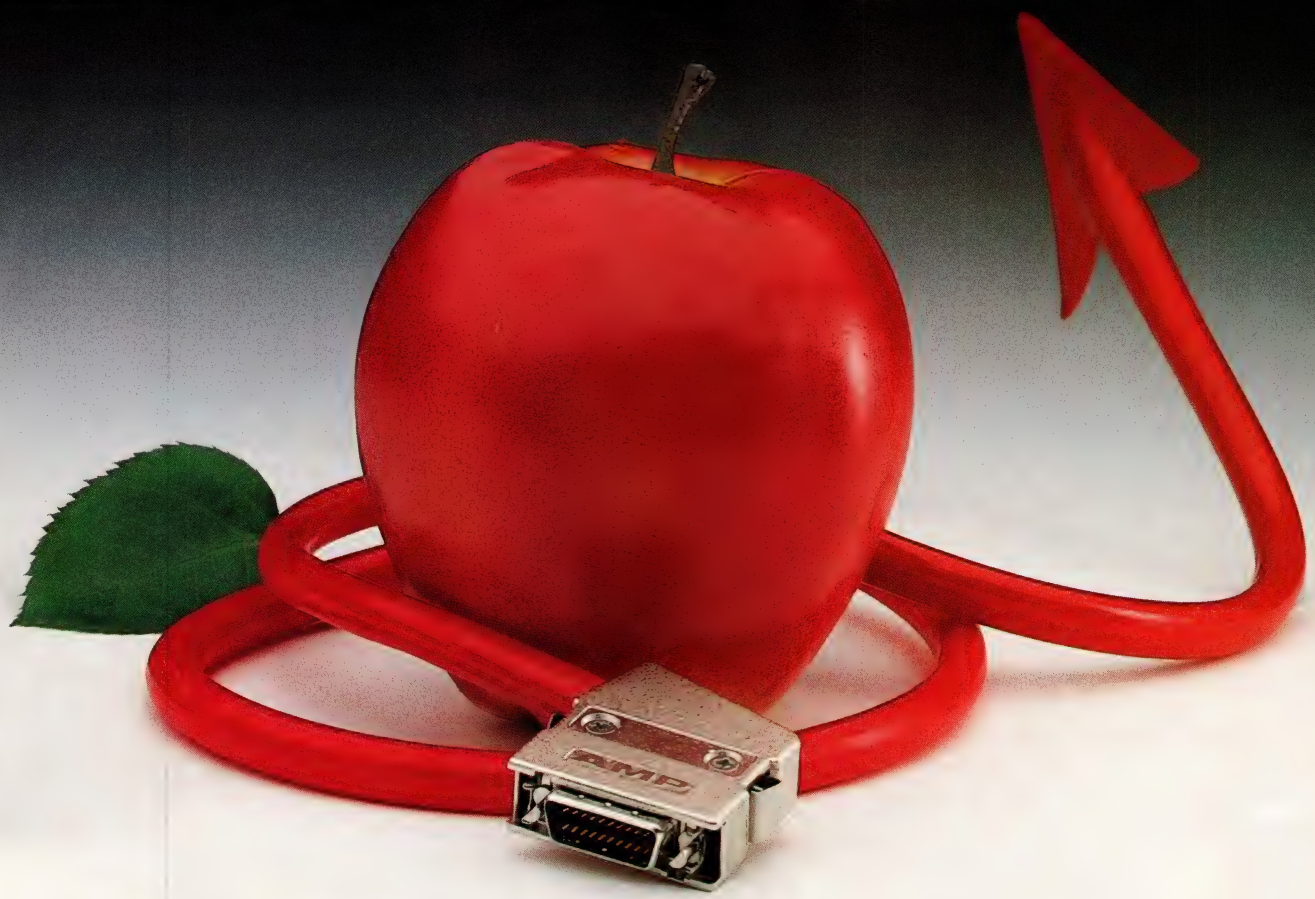
The D interface may look familiar, but our latest I/O connectors have some special temptations all their own.

Density, for instance. Mating contacts in a .050″ by .100″ pattern shrink I/O real estate dramatically, with sizes to 120 positions. Our staggered .075″ by .100″ pcb layout frees up more board, too, but still leaves trace routing uncomplicated.

And shielding, for another instance. All the effectiveness you expect from steel front shells and AMP engineering—plus our make-first/break-last design to handle electrostatic discharge concerns as well. Add superior strain relief, consider our squeeze-to-release option, and you have a compelling package.

AMPLIMITE .050 Series 50 and 68 position connectors were recently selected as the Small Computer Systems Interface (SCSI). The X3T9.2 Standards Committee anticipates approval as an ANSI standard in 1989.





Very tempting.

Maximum flexibility with right-angle, stacking, and edge-to-edge configurations. Fork-and-tab contacts minimize insertion/extraction force. Strict polarization, simple interface.

All part of our flexible AMPLIMITE .050 Series Connector line. Board-to-board styles feature the same .050 centerline, gold-over-nickel plated phosphor-bronze contacts. Thermoplastics are 94V-0 rated, and *everything* is compatible in design and material with robotic applications.

And our board-to-board configurations allow parallel stacking with minimal .472″ spacing, plus edge-to-edge, plus right angle configurations with pin or sockets.

Let us tempt you. Call the AMP Product Information Center at 1-800-522-6752 and ask about AMPLIMITE .050 Series Connectors. AMP Incorporated, Harrisburg, PA 17105-3608.

AMP Interconnecting ideas

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For long life and high reliability.
With capacities second to none worldwide: 2.0 Ah for the AA, 1.4 Ah for the 2/3 AA, 1.0 Ah for the 1/2 AA and 350 mAh for the 1/4 AA, the smallest type in the range.
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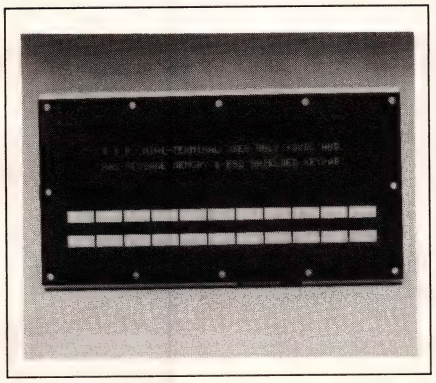
All modules employ a logic switch to control the output so they can share a common bus without having to employ external multiplexers. All units feature 1500V transformer-type isolation, 160-dB common-mode rejection, 74-dB normal-mode rejection, and ±0.05% accuracy. Linearity, drift, and input protection are ±0.02%, ±1 μV/°C, and 240V ac, respectively.

All modules in the SCM5B Series meet the transient protection requirements of IEEE-STD-472. The modules are housed in a 2.25×2.25×0.60-in. encapsulated package and operate over a −25 to +85°C range. Two 19-in., rack-mountable backplanes are available. The SCMPB01 provides 16 nonaddressable I/O signal channels; the SCMPB02 allows you to multiplex 16 channels onto a common analog bus. SCMB5 modules, $150; SCMPB01, $250; SCMPB02, $260.

Burr-Brown Corp, Box 11400, Tucson, AZ 85734. Phone (602) 746-1111.

Circle No 763



TERMINAL

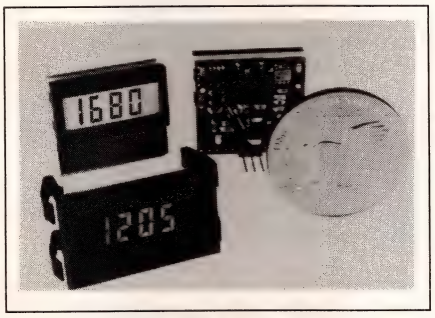
The Model 390X-03 terminal combines a 2-line×40-character vacuum-fluorescent display with a standard 2-row×11-column metal-dome keypad, which provides tactile feedback and features ESD shielding. Custom switch legends can be applied directly to the slide-in plastic strips, which come with the unit, to create a finished appearance, even during prototyping.

The keypad and display share a common RS-232C I/O. You can configure the unit as a data-terminal equipment (DTE) or data-communications equipment (DCE) device. It handles 1200 or 9600 baud data rates. The display provides both upper- and lower-case letters plus an expanded ASCII character set, which includes scientific and European characters in a 5×7 dot-matrix format.

The display characters are software-dimmable to three levels of brightness. The 390X-03 has 3k bytes of EPROM available for as many as 127 canned messages. $268.

IEE Inc, 7740 Lemona Ave, Van Nuys, CA 91409. Phone (818) 787-0311.

Circle No 764



AC-POWERED DPM

The Big-Little digital-process-control panel meter is designed for high-density applications. Panel-space needs measure only 2.3×1.0 in., and the behind-the-panel depth requirement is less than 1.3 in.

The line-powered DPM is available with either red or green backlighting for the LCD readout. With the backlighting, the meter is compatible with application environments ranging from complete darkness to full sunlight.

The meter's operating range spans −20 to +60°C. It includes overrange indication, a convenient screw-terminal connector, choice of bezel or window mount, process and dc inputs with span and offset adjustments for scaling in engineering

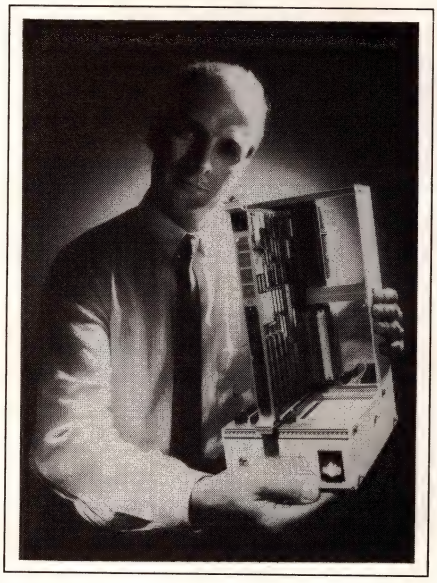
units, and ac inputs for current-transformer signals. $80 to $90 (OEM qty). Delivery, four to eight weeks ARO.

Modutec, 920 Candia Rd, Manchester, NH 03103. Phone (603) 669-5121.

Circle No 765

CARD FRAME

Fastframe's design features completely open sides to ease probing and simplify connection to the computer system under development. The unit is intended specifically for applications where conventional extender boards would present access



or loading problems.

The Fastframe consists of an L-shaped card cage complete with backplane, an 80W power supply, a power switch, a reset button, and 5V/12V outputs for flying-lead connection to disk drives. The frame accepts as many as seven standard- or half-height VME- or STE-bus cards.

The ability to access more than one card at a time increases the debugging effectiveness when looking for faults such as dynamic intercard communications problems. $1160 and $960 for versions with a 5-slot VME bus J1 and STE bus backplane, respectively.

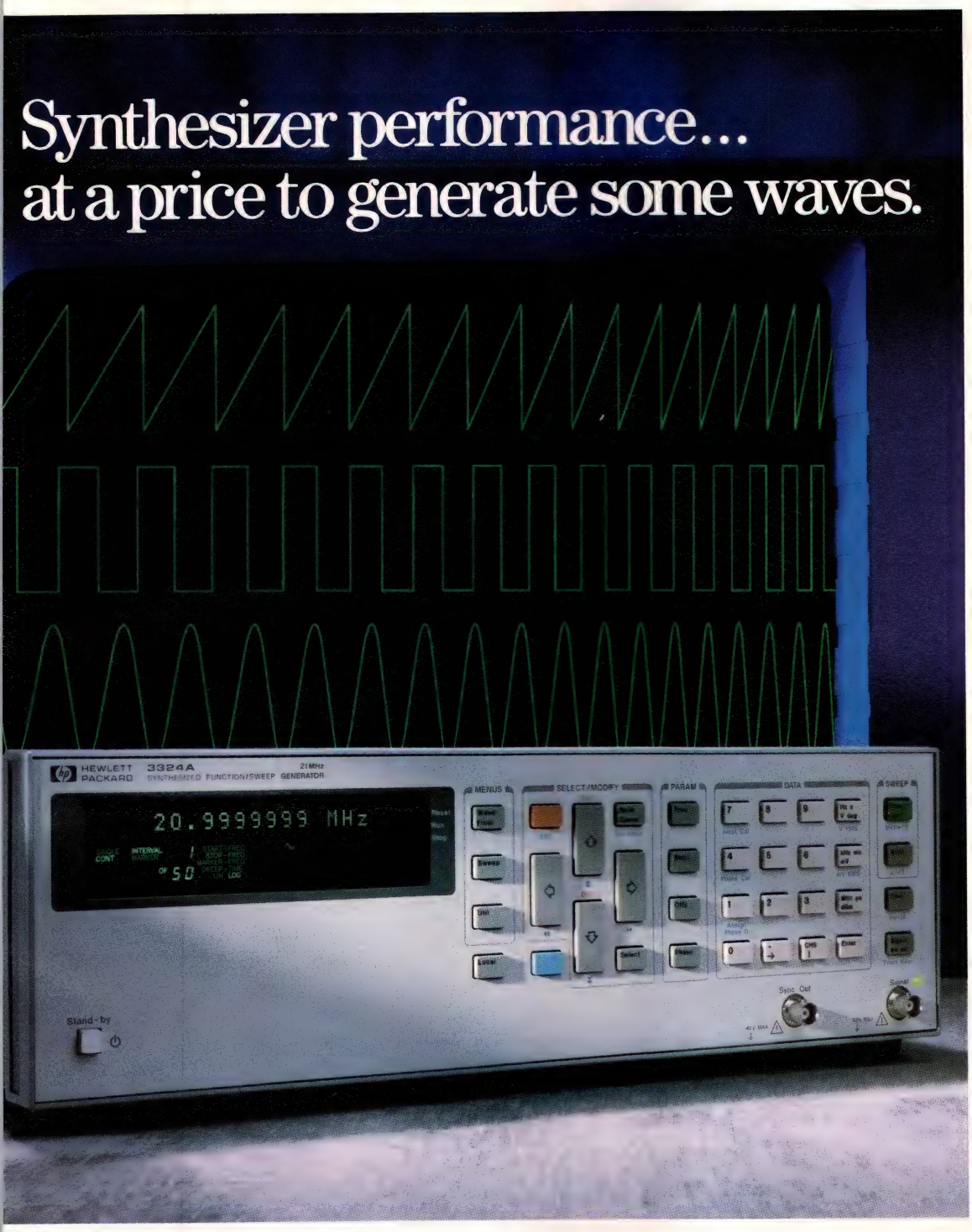
Dage Precision Industries, 46701 Fremont Blvd, Fremont, CA 94538. Phone (415) 683-3930.

Circle No 766

WORKSTATION

The Model 1448 PC-bus factory workstation is housed in an enclosure that meets NEMA 4 requirements to the panel level, and meets industrial quality standards throughout. It features a passive backplane architecture, speeds to 20 MHz, and a 14-in. graphic display, which functions with all standard CGA, HDA, and EGA graphics boards.

Synthesizer performance... at a price to generate some waves.



The new HP 3324A Synthesized Function/ Sweep Generator.

The low price of this new generator is bound to generate some waves. It's much less than you'd expect to pay for a function generator that has 5 ppm frequency accuracy, 9-digit frequency resolution and multi-interval sweep capabilities too.

Put it to work in testing filters and amplifiers where you need synthesizer accuracy, stability and signal purity. Tap its high linearity and multi-interval sweep features for A/D converter testing and for simulating rotating signals. Phase-lock two instruments together to calibrate phase meters and discriminators.

And there's more. Such as the high-stability frequency-reference option, and a high-voltage output option for making really big waves. To find out how low the price really is, call your local sales office today. Ask for our detail-packed brochure and application information.

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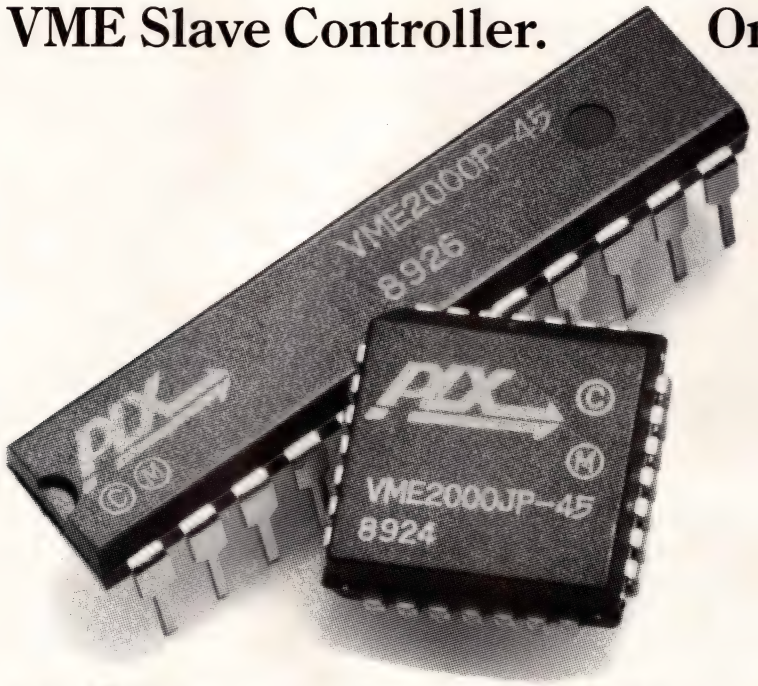

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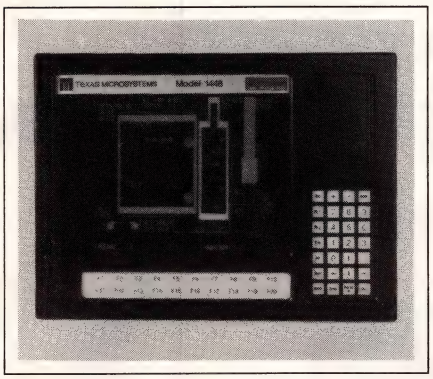
Industrial Product Showcase

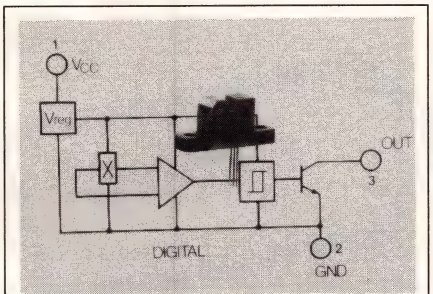


The workstation is equipped with nine PC/AT connectors. It accepts one or two 3½-in., half-height disk drives, fixed and/or floppy. The manufacturer's standard CPU cards used with the unit provide speeds from 10 to 20 MHz and onboard RAM capacity of 1M to 16M bytes. These CPUs are compatible with a variety of popular operating systems.

The MacroCard III optional I/O card provides one parallel and two serial ports, plus additional RAM capacity, graphics, and disk drivers. $7350.

Texas Microsystems Inc, 10618 Rockley Rd, Houston, TX 77099. Phone (713) 933-8050. FAX 713-933-1029.

Circle No 767



VANE SWITCH

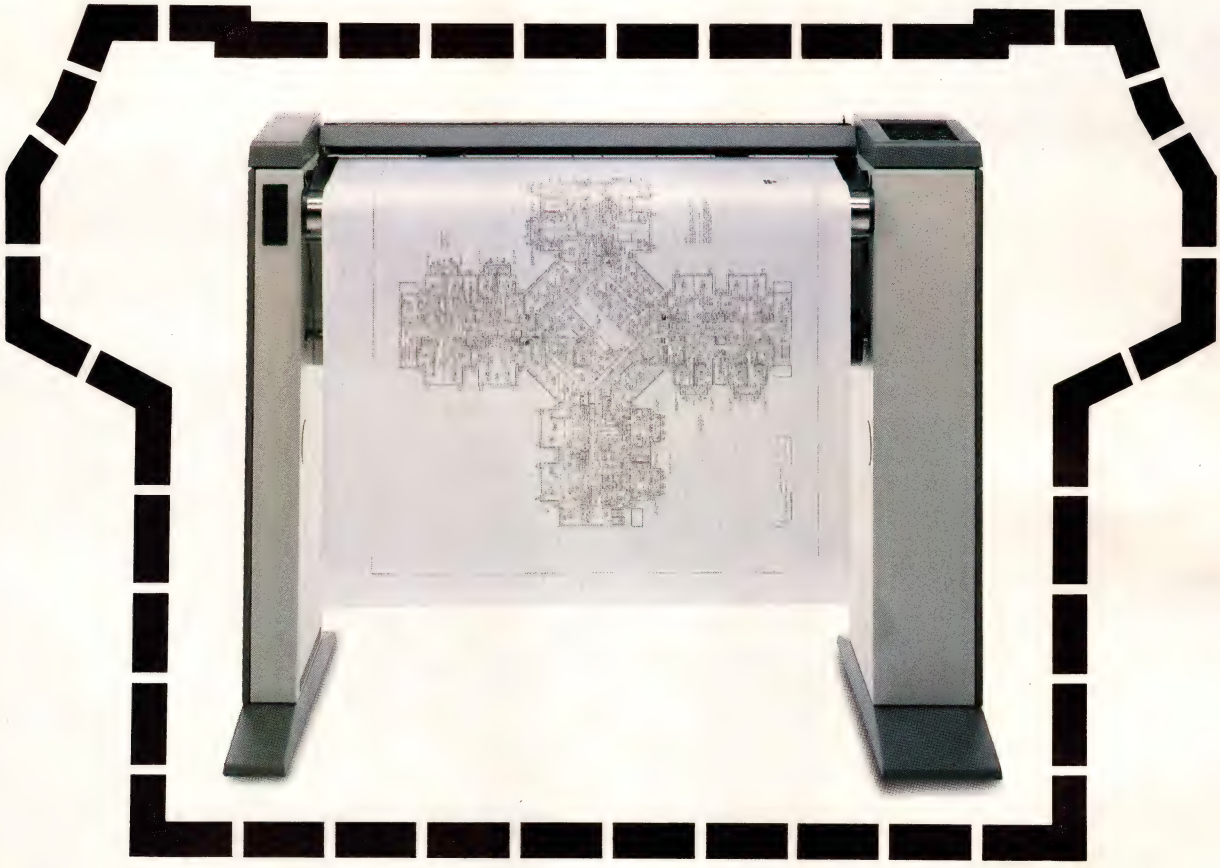
The UMN6450X Hall-effect vane switch is housed in a rugged plastic package, which contains and protects an activating magnet and all required sensing and signal-conditioning circuitry. The package is configured to form a channel that precisely defines the travel path of a user-supplied ferromagnetic vane.

Lack of physical contact between the vane and the switch package is a key feature of the UMN6450X. The unit is designed to operate in noisy environments and to tolerate poorly regulated supplies. The internal Schmitt trigger provides hysteresis for greater switch-point immunity to electrical noise and vane imperfections. The on-chip regulator allows the switch to operate with supply values ranging from 4.5 to 24V.

The switch output can sink as much as 20 mA at a rated repetition rate of 100 kHz and directly interface with bipolar and MOS logic devices. The switch has a −20 to

XEROX

Versatec announces drastic reductions on electrostatic plotters.



Introducing a plotter that's half the usual size and weight.

And half the price you'd expect to pay for electrostatic performance.

Yet our 8500 Series gives you all the quality you've come to expect from Versatec. The leader in electrostatic technology for over two decades.

And while squeezing down the size of our plotters, we managed to squeeze out a lot more performance. The plot time is drastically reduced because the information is processed by the plotter, freeing your computer for other projects.

Also note that compared to pen plotters,

the 8500 has 6 to 20 times more throughput.

Now that's fast. But the 8500 Series is easy to handle as well. Media loading is up front. You simply plug in the system and it's ready to plot.

A unique user-friendly keypad takes anyone through the plotting process quickly, easily and in plain English. A built-in micro-floppy drive stores plotter setups and configurations on-disk. Which means no more time-consuming setups.

The 8500 Series is also the first plotter that's literally ready-to-roll. Its built-in casters let you move quickly to any location for sharing. You can also share the 8500 through networking with a plot server.

With optional features the 8500 also automatically cuts and winds plots. Up to 999 copies, overnight, completely unattended if you want. And it's available in both 400 and 200 ppi resolution, in either 24" or 36" formats.

You also get full support for 906/907 and HP-GL pen plotter data formats. So designers have the freedom to use virtually any major CAD package they choose.

Incidentally, the same technology that reduces the size of the 8500 also makes it three to four times more reliable than the industry standard. Which means you'll have little need for the most comprehensive service and support organization in the world.

For more information on our 8500 Series, call our toll-free number now: (800) 538-6477;

in California, (800) 341-6060.

But do it now. Because choosing any other electrostatic plotter could have drastic consequences for your budget.

VERSATEC

We deliver performance.

Versatec Inc.
2710 Walsh Avenue, Santa Clara, CA 95051
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+85°C operating range. $2.16 (1000). Delivery, stock to 12 weeks ARO.

Sprague Semiconductor Group, 70 Pembroke Rd, Concord, NH 03301. Phone (603) 224-1961.

Circle No 768

ENCLOSURES

Series 33 aluminum enclosures feature a sturdy U-shaped section, which also forms their base and sides to provide good stability. Slots in the base and sides directly accommodate a circuit board without the need for additional mounting hardware.

Easy assembly is another feature of the enclosures. You use the same screws to fasten both the cover and the front/rear panels to the U-shaped section. Press-fitted bezels conceal all the screws to enhance cabinet appearance.

The fully enclosed design also ensures good screening. Special front panels provide sealing that conforms to IP 54/NEMA 4 standard. Available accessories include a handle, slotted mounting plates for ventilation, card-carrier fittings for Eurocards measuring 100 × 160 mm with connectors, double Eurocard mounting sets, and receptacles for disk drives. From $35.

Elma Electronics Inc, 41440 Christy St, Fremont, CA 94538. Phone (415) 656-3400.

Circle No 769

EXPANSION CHASSIS

The SA-H187 is a dual-drive expansion chassis designed for applications requiring disk drives in rugged environments. Each drive is shock-isolated within a removable drive canister for protection in harsh environments.

The drive canisters include an ESDI or SCSI interface. The chassis is available in three versions: ESDI controller/drives, SCSI controller/drives, and SCSI controller supporting ESDI drives via an optional SCSI-to-ESDI adapter.

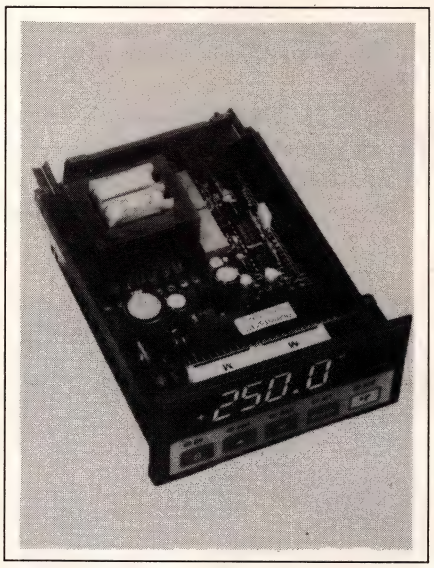
The SA-H187 contains a front console with drive-power on/off switches and drive-status LED in-

dicators. The off switch position deactivates an interlock solenoid, which releases each drive canister so it can be removed from the chassis. The interlock also prevents removal of a canister before the drive spins down.

The rack-mount chassis includes a shock-mounted power-supply unit that contains a separate power-supply module for each drive and a third module for the exhaust fans. $4150.

Sigma Information Systems, 3401 E LaPalma Ave, Anaheim, CA 92806. Phone (714) 630-6553. FAX 714-630-5417.

Circle No 770



CONTROLLERS

Available with 3-, 3½-, 4-, and 4½-digit displays, SDC and SDI Series μP-based process controllers measure and monitor a variety of variables—voltage, resistance, current, frequency, temperature, and rpm/flow rates—at a touch. All units have a blinker-display function for overrange, underrange, or burnout, and are housed in UL-94V-1-rated plastic cases.

These smart display controllers operate from 115/230V power sources and feature digital and analog communication interfaces. The units generate easy-to-read prompts on the front-panel display screens. By following these prompts, users set high or low limits, range, time delay, and adjustable differential. Because there are no DIP switches or potentiometers to adjust, no tools are required.

The controllers' built-in alarm relays have an adjustable differential (0 to 10%) and time-delay capability ranging to 100 sec. A simple prompt program, which is fingertip operable from the front of the panel, allows you to calibrate the controllers. From $285.

CG Instruments Corp, 434 Windsor Park Dr, Dayton, OH 45459. Phone (513) 434-6952. FAX 513-434-7643.

Circle No 771

TEXAS INSTRUMENTS

A PERSPECTIVE ON DESIGN ISSUES:

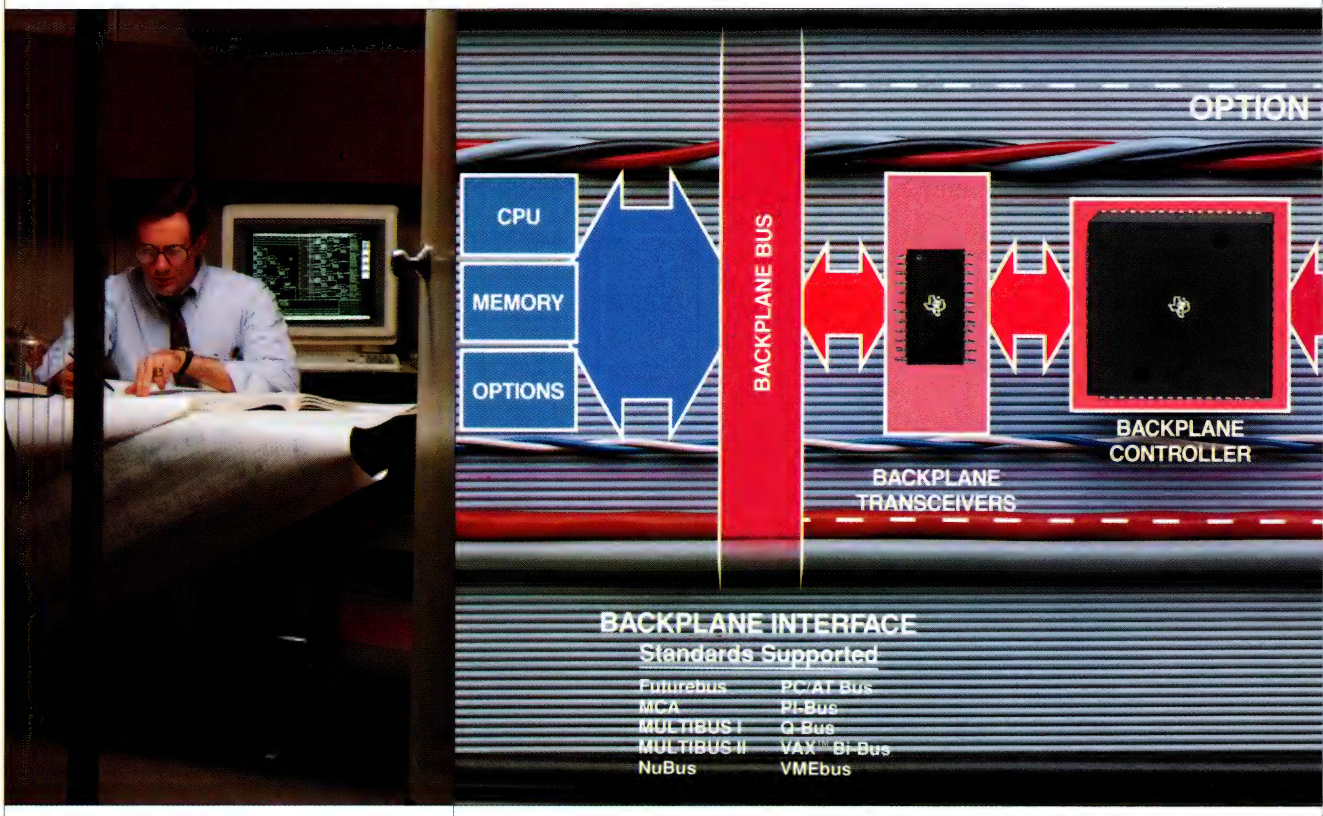
Getting on and off the bus faster

IN THE ERA OF

MegaChip TECHNOLOGIES

New bus interface ICs from TI can keep your total system up to speed.

You not only increase system throughput but cut power and conserve real estate at the same time.



High-speed, low-power implementation of backplane and peripheral interfaces for most popular standards is made possible by TI's comprehensive family of both digital and analog physical-layer

What use is a high-performance CPU if its processing power can't be delivered to the backplane and outward to the peripherals?

Typically, some system throughput is lost at the local bus interface, some at the backplane interface, and some at the peripheral bus interface.

To help you minimize such losses and maximize system throughput, Texas Instruments offers a series of innovative chips for (1) backplane interface and (2) peripheral bus interface, as well as (3) controllers to regulate data flow.

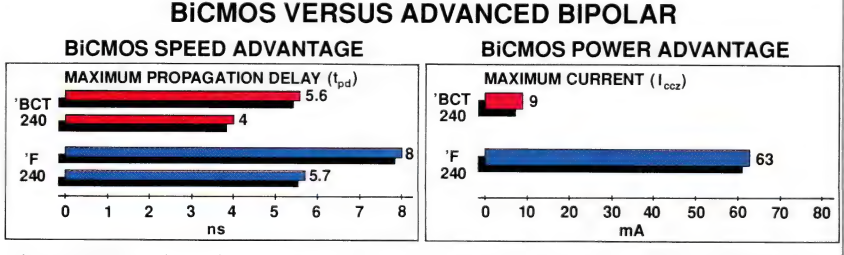
These devices support the major industry standards listed above so that you can achieve system compatibility regardless of the bus you are implementing.

Superior backplane interface performance

To maximize system throughput, data must be able to get on and off the bus quickly. Therefore, the backplane bus transceivers must be capable of high speed and high drive.

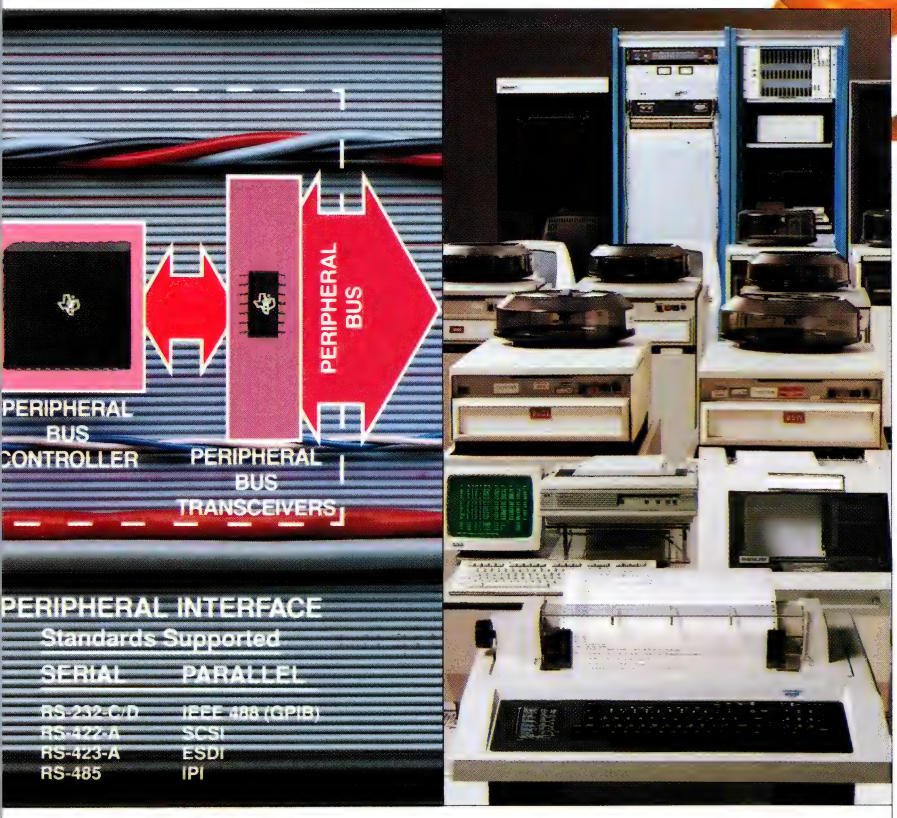
Our high-speed/low-power BiCMOS logic (SN54/74BCTXXX) is specifically designed for bus interface applications.

As the name implies, TI BiCMOS merges low-power CMOS with high-speed bipolar, delivering switching speeds comparable to advanced bipolar devices. You also get the 48/64-mA



The BiCMOS lead over bipolar is proven by this comparison between TI's '74BCT240 and a comparable advanced bipolar standard device. Typical propagation delay of TI's BiCMOS part is faster *(left)* while power dissipation is less *(right)*.

TI's MegaChip™ Technologies are the means by which we can help you and your company get to market faster with better, more competitive products. Our emphasis on volume manufacturing of high-density circuits is the catalyst for ongoing advances in how we design, process, and manufacture semiconductors and in how we serve our customers.



ICs. To complete the implementation, TI offers a series of innovative standard and ASIC control devices. Use of TI's leadership bus interface devices can help shorten system design cycles.

drive current you need, and total system power savings can be as high as 25% (*see charts*).

There are more than 60 members in our BiCMOS family, including 8-, 9-, and 10-bit latches, buffers, drivers, and transceivers. The family is also available in military versions.

Our family of octal ECL translators (SN10KHT/100KTXXXX) delivers a low-power, high-speed translator solution with 48 mA of drive capability on the TTL side.

Our high-speed Futurebus transceiver family (SN55/75ALS-05X) includes quad and octal devices compatible with Futurebus implementations of the IEEE 896.1 standard. With a drive capability of 100 mA, a 5-ns (typ) propagation delay, and a supply current of 65 mA (max), our SN75ALS053 has the best speed/power ratio of any Futurebus transceiver on the market today. ■

High-performance peripheral interfaces

Peripheral bus interface design decisions revolve around trade-offs between line length, data rate, and noise immunity.

Where data rates are low and line lengths are short, as with the popular RS-232-C/D standard, the major concern is power savings. However, relatively high voltages (30 V) prevent the use of standard CMOS devices. Your answer lies with TI's Linear BiCMOS family.

Included are low-power versions of industry-standard quad drivers and receivers (SN75C188/89). Driver/receiver combinations, ranging from single to quad combinations (SN75C1154), substantially cut package count.

This BiCMOS technology will also allow us to provide charge pump circuitry for single 5-V operation.

Where data rates are high and line lengths are long, as the newer peripherals demand, noise can become a major problem. It is overcome by the use of differential drive. Typically, the major application requirement is higher speeds at, ideally, lower power.

For example, disk drives using ESDI, IPI, or SCSI interfaces will benefit from TI's SN75ALS17X devices conforming to RS-422-A and/or RS-485 standards. These chips are fabricated using our unique IMPACT™ processing that delivers up to 50% greater speed compared to competing products with as much as a 30% power reduction.

IMPACT processing is also behind the unmatched speed of our SN75AS030 RS-422 dual driver/receiver. Typical propagation delays are only 6 ns. ■

No matter which of TI's innovative devices you choose to improve speed, cut power, and reduce real estate at the media interface, the complete bus interface requires another element — controllers. *For details on how TI is addressing your needs in this area, turn the page.*

High-performance controllers make system design easier.

While the majority of physical-layer devices—those used to implement backplane and peripheral interfaces—transmit data, your system design also requires a device to regulate the flow of that data through the bus interface. To do the job, TI offers a series of controllers that simplify and shorten your task while cutting chip count and improving overall system throughput.

Simplified NuBus design

TI has taken much of the work out of NuBus™ design by introducing the industry's first standard NuBus interface devices. They are the SN74ACT2440 NuBus Controller and the SN74BCT2420 NuBus Registered Transceiver.

A typical implementation, using two 16-bit transceivers and one 32-bit controller (*see below*), replaces as many as 45 discrete devices. Compared to a discrete approach, this solution uses 60% less board space and 90% less power.

Because the necessary logic is embedded within the controller, design cycle time is reduced significantly.

A low-power UART

There is now more need than ever for low-power RS-232 interfaces. Our TL16C450 Universal Asynchronous Receiver/Transceiver (UART), made with CMOS process technology, is an excellent choice for desktop applications and is especially suited for use in laptop/battery-powered units.

A flexible SCSI controller

Available soon, our SCSI controller (designed to conform to ANSI X3.131-1986 specifications) will deliver data rates of 3 Mbytes/s (asynchronous) and 5 Mbytes/s (synchronous).

Unique byte-stacking control logic will allow interface to 16-, 24-, and 32-bit buses. The TI controller will also provide powerful multiphase SCSI commands, including automatic handling of save-data pointer to minimize interrupts to the host processor. Dual 32-byte FIFOs will provide smooth, efficient buffering between processor and DMA ports.

Customized controllers, too

The NuBus and UART controllers are available as part of our ASIC standard-cell library.

In addition, TI offers TGC100 Gate Arrays and TSC500 Standard Cells as part of our ASIC family which allows you to build the precise chip functions you need. ■

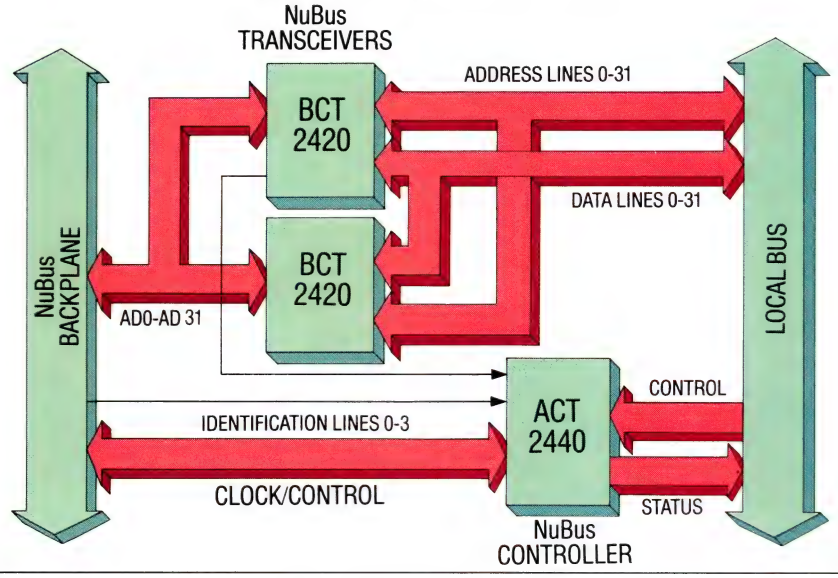
System complexity and the future

As systems become more and more complex, the need will emerge for combining the functionality of controllers and physical-layer devices on a single chip. To that end, TI is applying its acknowledged expertise in physical-layer devices to the design and development of such advanced control-level ICs.

System complexity also brings with it the need for simulation models to make design easier and faster. As a result, we already have simulation models available for more than 1,300 TI devices, including BiCMOS bus interface and ACL logic devices.

Another issue is the increasing difficulty and expense of testing boards in complex systems. Consequently, TI supports the JTAG/IEEE P1149.1 standard with the development of standard products and ASICs having on-chip test cells, as well as with development support software and device models on several leading workstations. ■

TI's 32-bit NuBus Interface Solution



Major space savings are realized by using one TI SN74ACT2440 controller and two SN74BCT2420 transceivers to complete a full 32-bit NuBus master/slave interface. As many as 45 discrete logic devices are replaced, realizing significant reductions in board space, power consumption, and design cycle time.

Please call **1-800-232-3200, ext. 3905**, for your copy of our Bus Interface Devices brochure. Or write Texas Instruments Incorporated, Dept. SSY25, P.O. Box 809066, Dallas, Texas 75380-9066.

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 08-8444

TEXAS INSTRUMENTS

386-based CPU and controller boards form core for extended STD Bus systems

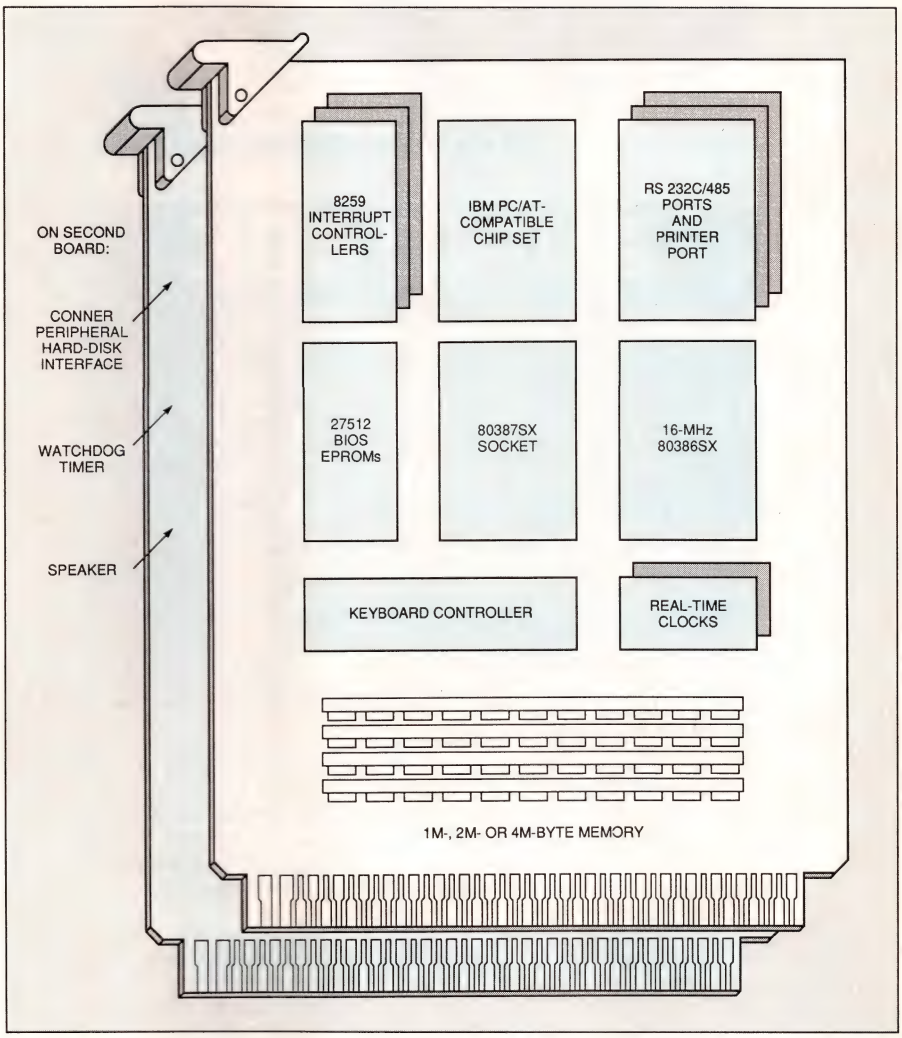
The 8-bit STD Bus is widely used in applications for medical equipment and image recognition in industrial environments. However, systems are becoming more sophisticated, and the bus is running out of computational and processing power. System manufacturers are in a dilemma: They can go to a wider bus, such as Nubus or Futurebus, but they then give up their STD Bus experience and hardware and software. In addition, the small size of the STD card, 4.5×6.5 in., and the fact that it's supported on three sides makes the STD Bus card well suited for an industrial environment.

Ziatech Corp recently proposed the STD 32 Bus, a 32-bit version of the STD Bus that allows full, nonmultiplexed 32-bit-wide data and address transfers, while maintaining compatibility with old 8-bit boards. The company proposes that a second row of connector pads be added between the relatively widely spaced existing row of pads.

This technique is similar to that used by the EISA bus, the 32-bit extension to the 16-bit IBM PC/AT bus. The bus takes advantage of the connector technology developed for the EISA bus (**Fig 1**) by companies such as Burndy Corp (Norwalk, CT). Note that the smaller pads can carry less current than the larger lower pads. The lower pads can carry 3A, and the smaller pads carry 1.5A. However, there are double the number of 5V pads present on the upper row for carrying power and more than double the number of ground pads.

The company's first product for the new bus, the ZT 8910, is a 2-board CPU that serves as a transition product between the old 8-bit bus and the 32-bit extended bus. The STD 32 Bus has an 8-, 16-, and 32-bit mode; the ZT 8910 automatically senses whether it's plugged into the 8-bit STD Bus or the 32-bit STD 32 Bus and configures itself for an 8- or 16-bit mode. So you can do all of your software and hardware development on the existing 8-bit STD Bus and then move your boards to the STD 32 when it becomes available in mid-1990.

The board has a 16-MHz 386SX processor and uses the Chips and Technologies (San Jose, CA) IBM PC/AT-compatible chip set. (The 386SX is a 16-bit version of the 80386.) The ZT 8910 will run on the STD 32 in the bus's 16-bit mode; the bus also has an 8-bit as well as a 32-bit mode. The board's features include 1M, 2M, or 4M bytes of dynamic RAM, 32k bytes of battery-backed RAM, a 387SX numeric



Compatible with both the 8-bit STD Bus and the 32-bit STD 32 Bus, *the ZT 8910 provides a growth path between the two buses. The larger lower pads are the original STD Bus pads, and the smaller upper pads carry the additional STD 32 Bus signals.*

UPDATE

coprocessor socket, a user DMA channel, two serial communications ports, a printer port, a keyboard, a Conner Peripheral (San Jose, CA) hard-disk controller, three 16-bit counter/timers, three interrupt controllers (one cascadable), and a 2-stage watchdog timer. (A 1-stage watchdog timer forces an unconditional CPU reset; a 2-stage watchdog timer forces a jump in software to a recovery subroutine as a first stage and performs a CPU rest only if the first-stage subroutine commands it.)

In addition to the CPU, Ziatech is introducing the ZT 8980 VGA and keyboard interface, and the ZT 8950 high-density floppy-disk controller. The ZT 8980 is based on the Paradise VGA chip. When used in an STD 32 system, the 8980 performs 16-bit video data transfers. The ZT-8950, based on the Intel 82077 floppy-disk controller, supports both 3½- and 5¼-in. disk drives.

The ZT 8910 will cost approximately $2700, the price of the ZT 8980 will be $700, and the ZT 8950 will cost $350. All three units will be available in the first quarter of 1990.—***Margery Conner***

Ziatech Corp, 3433 Roberto Ct, San Luis Obispo, CA 93401. Phone (805) 541-0488. FAX 805-541-5088.

Circle No 732

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SONY HIGH-SPEED, HIGH-DENSITY SRAMS.

MODEL	CONFIG-URATION	SPEED (ns)	PACKAGE
CXK5863P	8K x 8	25/30/35	DIP 300 mil
CXK5863M	8K x 8	25/30/35	SOP 450 mil
CXK5863J	8K x 8	25/30/35	SOJ 300 mil
CXK5464AP	16K x 4	25/30/35	DIP 300 mil
CXK5464AJ	16K x 4	25/30/35	SOJ 300 mil
CXK5465P*	16K x 4	25/30/35	DIP 300 mil
CXK5465J*	16K x 4	25/30/35	SOJ 300 mil
CXK5164P	64K x 1	25/30/35	DIP 300 mil
CXK5164J	64K x 1	25/30/35	SOJ 300 mil
CXK5971P	8K x 9	25/30/35	DIP 300 mil
CXK5971J	8K x 9	25/30/35	SOJ 300 mil
CXK58258AP	32K x 8	25/30	DIP 300 mil
CXK58258AJ	32K x 8	25/30	SOJ 300 mil
CXK58258P	32K x 8	35/45	DIP 600 mil
CXK58258SP	32K x 8	35/45	DIP 300 mil
CXK54256P	64K x 4	35/45/55	DIP 300 mil
CXK51256P	256K x 1	35/45/55	DIP 300 mil

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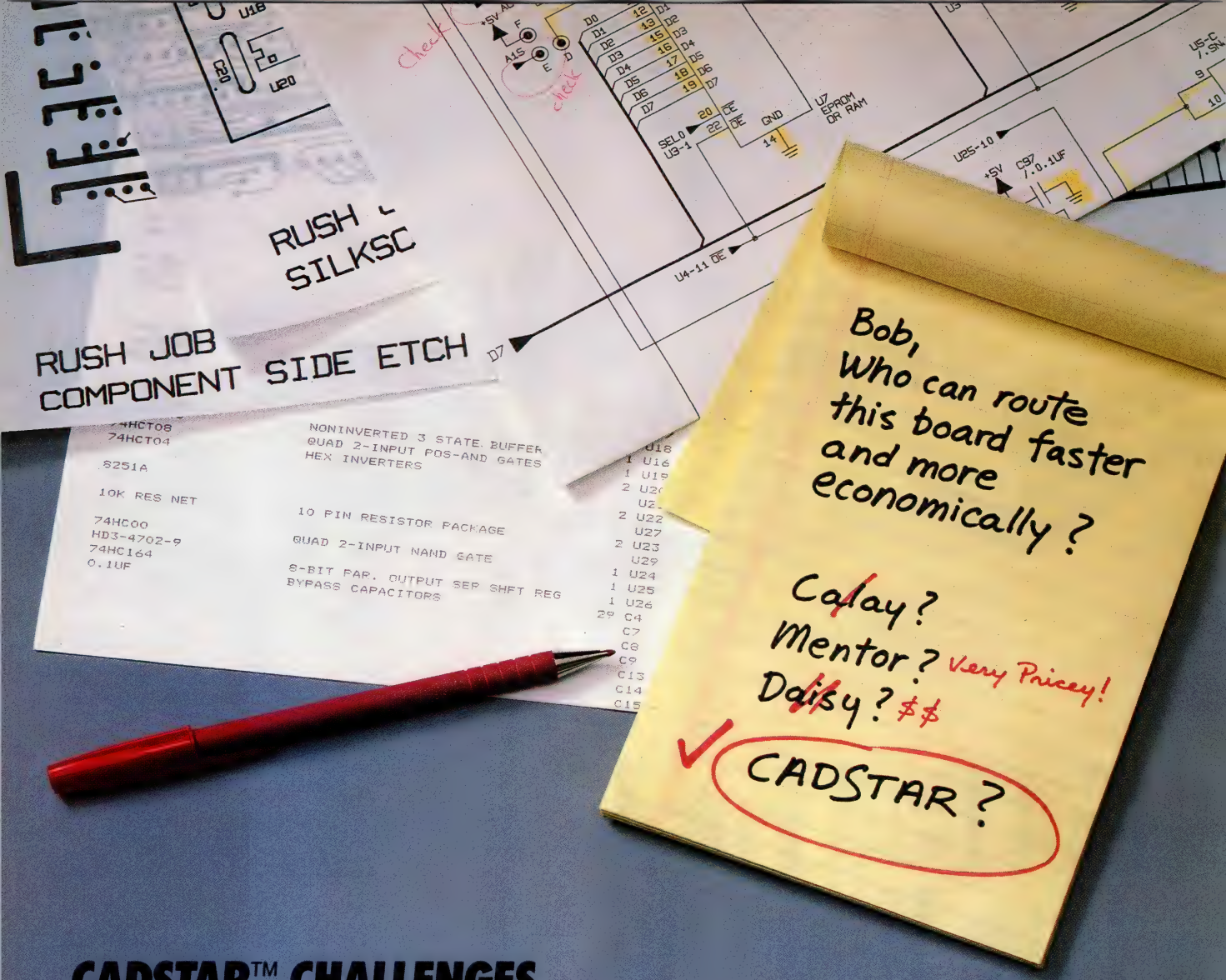

CADSTAR™ CHALLENGES WORKSTATION ROUTERS...

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The CADSTAR 386 Advanced Router is the fastest, most economically priced PC-based 32-bit gridless router in the business. And we challenge the competition to match its results.

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CIRCLE NO 85

Scan-test module converts ASIC verifier into industry-standard verification tool

The Scan-Test Module is a plug-in board for the Logic Master XL that allows you to verify your ASIC using both parallel-vector testing and serial scan-mode evaluation. The board, which adds $33,000 to the Logic Master XL's starting price of $55,000, uses the XL's pin electronics and includes four high-performance drivers per board. The board can store 1 million sequences of 4-bit data per driver, configured to represent whether to drive the ASIC pin high or low, whether to sense a high or a low from the ASIC pin, whether the pin is 3-stated or masked, and whether the data should be acquired. You can stack the memory to achieve memory depths of 2 million sequences with 2 channels or 4 million sequences with 1 channel.

If you want to use parallel vectors to set up certain test conditions, you can toggle between parallel and serial execution. You can switch without any software overhead unless you use different clock speeds for parallel and serial data, or you use some pins in both parallel and serial modes, or your patterns contain loops.

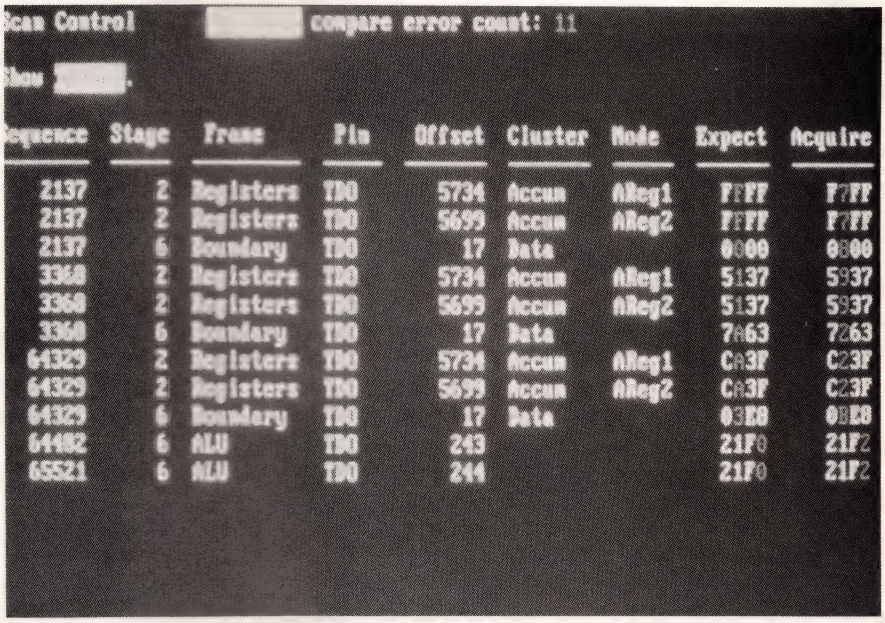
The integration of the Scan-Test Module into the Logic Master XL lets you move between scan, functional, and parametric verification of your ASICs at speeds as high as 60 MHz. The module supports a superset of the Joint Test Action Group's (JTAG) proposed scan-test specification, which is being considered by the IEEE as P1149. Other scan implementations supported include scan path, scan set, random-access scan, boundary scan, and level-sensitive scan.

For test methodologies where you need more than the four serial channels, you can add more scan-test modules to the Logic Master XL; it accepts as many as seven, giving you as many as 28 channels of 1-million-sequence-deep memory.

Software included with the Scan-Test Module lets you reconfigure the module's memory, trading channels for memory depth. The software also formats the on-screen display of your scan input and output data. You can specify that the data be displayed as unformatted, raw data; as error-only scan frames; or as user-definable groups of bits. Additionally, you can use patterns generated by simulators from Gateway Design Automation (Lowell, MA) and Teradyne EDA (Santa Clara, CA) for your ASIC verification.—***Michael C Markowitz***

Integrated Measurement Systems Inc, 9525 SW Gemini Dr, Beaverton, OR 97005. Phone (503) 626-7117. FAX 503-644-6969.

Circle No 731



Software with the Scan-Test Module *lets you control the screen display. One display mode highlights all errors from a verification run to help you debug your ASICs.*

NVG COMPATIBILITY FROM THE PILOT'S POINT OF VIEW.

Day or night, pilots see exactly the information they need with Korry's new NVG-compatible switchlights and panels. Clearly and comfortably, without hot spots or light leaks. All thanks to the most uniform brightness—and the truest red—in the entire industry.

Today, Korry NVG-compatible switchlights are being used by pilots flying the Black Hawk HH-60H, the world's first production-version MIL-L 85762-compliant Helicopter Combat System.

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Single-slot STD Bus module replicates IBM PC/XT

The CPU-XT single-slot STD Bus module includes all the functions typically found inside an IBM PC/XT computer except disk drives and a power supply. The module can host an Intel 8088 or NEC V20 μP at clock speeds as fast as 9.54 MHz. The module measures 6.5 × 4.5 × 1 in.

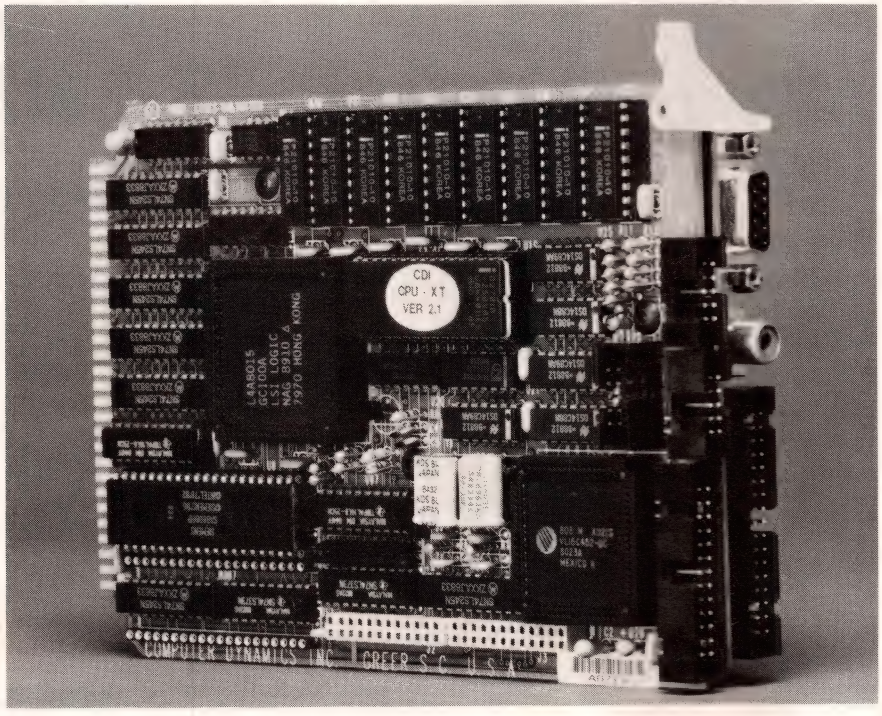
Several companies supply STD Bus products that offer IBM PC compatibility. The CPU-XT, however, replicates the entire IBM PC/XT on a single STD Bus card. The card includes the μP, 128k bytes of EPROM, 256k to 640k bytes of RAM, a keyboard interface, a timer, and a battery-backed clock calendar. Furthermore, the product includes a standard floppy/Winchester disk controller and a graphics controller.

The onboard disk controller can interface to two floppy and two Winchester disk drives. The onboard graphics controller offers compatibility with monochrome, IBM CGA, plasma, and LCD displays. The STD Bus module also includes serial and parallel ports.

Target markets for the module include applications in OEM enclosures and rugged industrial applications. You can use the module in a ROM-based embedded application or with disk drives. The module can address all STD Bus I/O devices and as much as 64k bytes of STD Bus memory. The CPU-XT costs $995.—***Maury Wright***

Computer Dynamics, 107 S Main St, Greer, SC 29650. Phone (803) 877-8700.

Circle No 730



A completely PC/XT-compatible module in a single STD Bus card, *including disk and graphics controller, sets the CPU-XT apart from other STD Bus products that offer compatibility with IBM Personal Computers.*

In 1979, Margaret Thatcher is voted in as Prime Minister of Great Britain...

and EDN is voted #1 in readership.

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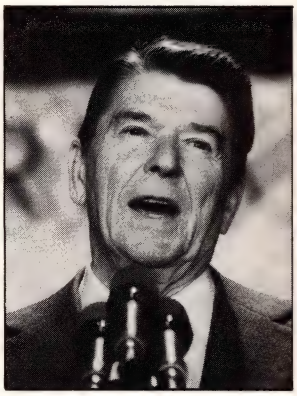

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In 1981, Sandra Day O'Connor is the 1st woman on the Supreme Court...

and EDN is first in readership.

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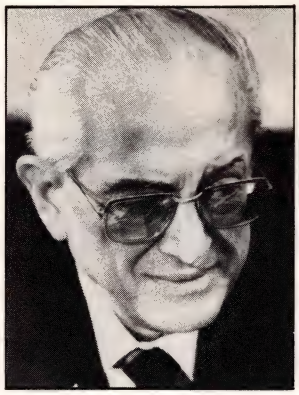
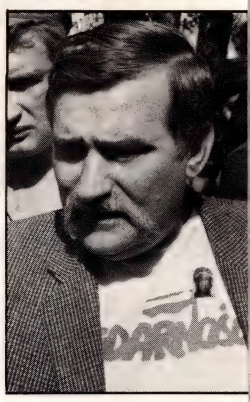


and EDN leads as #1 in readership.

In 1983 Lech Walesa of Poland wins the Nobel Peace Prize...



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Sipex Corporation	#1	4
Kyocera Northwest, Inc.	#1	NOT INCL.

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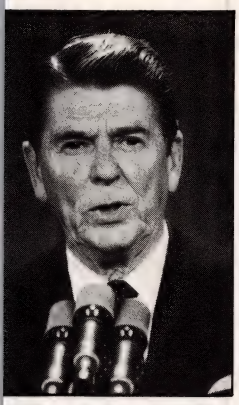
*Independent studies are conducted across customer/prospects lists or TIDS lists, not across a magazine's or newspaper's own list, which results in obvious bias. **Results based on the question

984, Ronald Reagan
e-elected #1 in a
dslide...



EDN is re-elected #1
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In 1985, Mikhail Gorbachev
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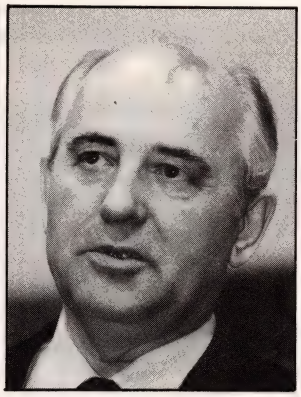

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leader in readership.

In 1986, Corazon Aquino
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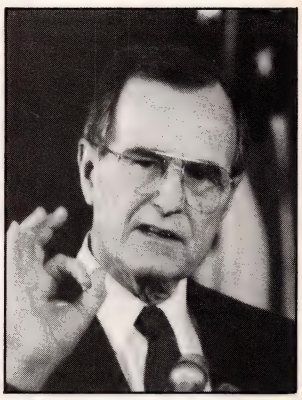

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2	4	3	NOT INCL.
4	3	2	NOT INCL.
2	4	3	6
2	3	4	NOT INCL.
2	NOT INCL.	3	NOT INCL.
3	2	4	5

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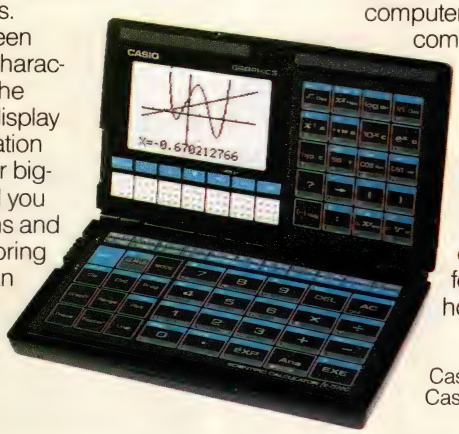

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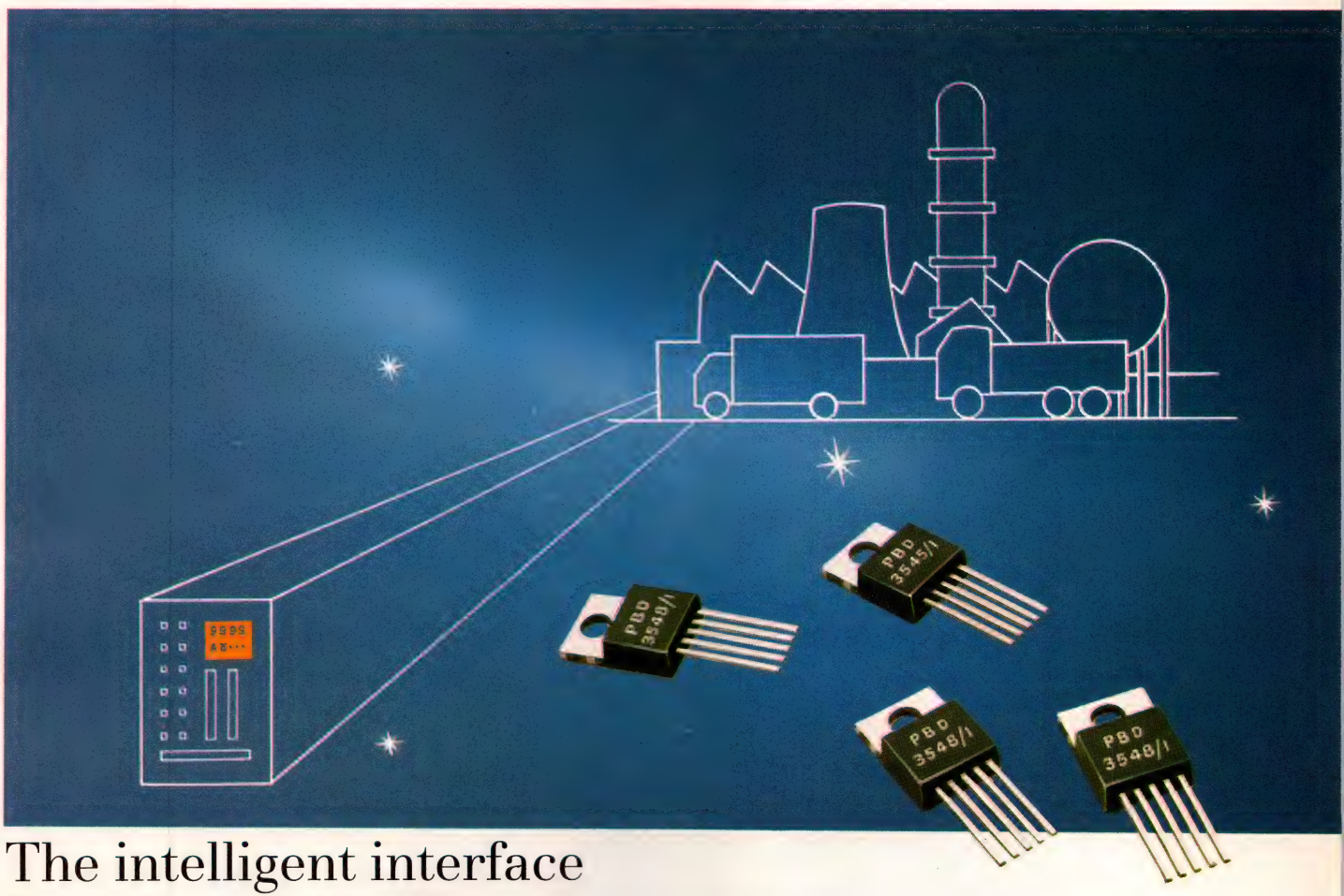

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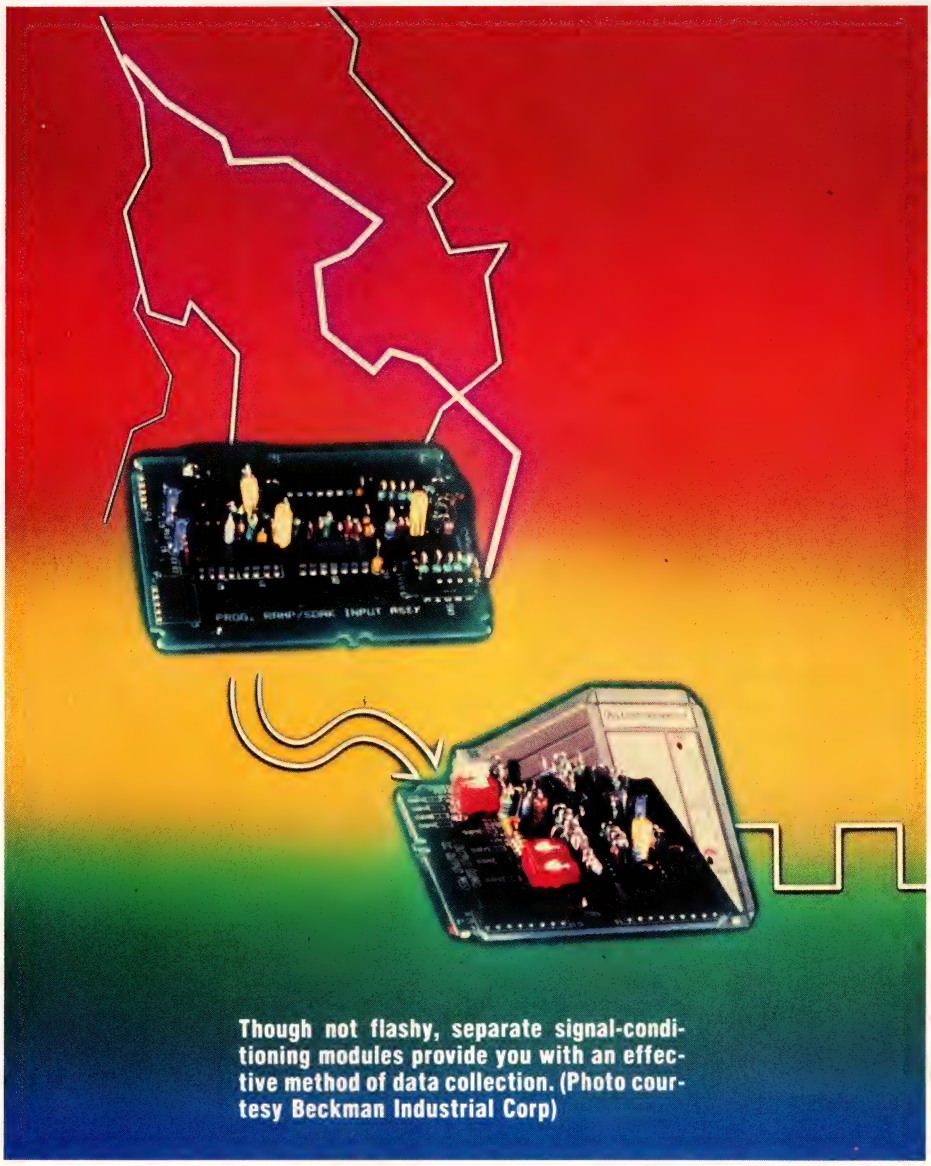
We're in the lead

CIRCLE NO 116

Signal conditioners



Though not flashy, separate signal-conditioning modules provide you with an effective method of data collection. (Photo courtesy Beckman Industrial Corp)

A wide variety of products can manipulate signals such as transducer outputs, safely and conveniently preparing them for collection and processing by computer-based data-acquisition systems.

Dan Strassberg, Associate Editor

Whether your application is automatic test, factory automation, process control, or instrumenting a laboratory experiment, if you are dealing with transducer outputs, sensing the status of contacts carrying high voltages, or even supplying signals to actuators such as valve positioners, you can't avoid signal conditioning. Signal conditioning means performing such operations as buffering, amplifying, attenuating, isolating, and linearizing the transducer signals (see **box,** "Transducers—the variety is endless").

There are many ways to include the signal-condition-

ing function in your system. If you have the expertise and can justify the effort, you can design the circuits yourself. Alternatively, you can select products from a list of categories that includes the following:

- Transducers with built-in signal conditioning—possibly ones with digital outputs
- Process-variable transmitters
- Data loggers (which generally allow you to include proprietary signal-conditioning modules)
- Indicating instruments that incorporate signal conditioning—including certain digital panel meters
- Remote input/output subsystems.

Another technique—the focus of this survey—is the use of separate signal-conditioning modules. Such circuit modules, many of which are listed in **Table 1**, have been steadily gaining favor over the past decade. These units, mounted singly or in groups close to the transducers, can have analog or digital system interfaces. At present, analog interfaces still predominate, except, of course, where the data is inherently digital (for example, when a conditioner monitors the status of a relay contact).

Historically, signal conditioning has been a low-profile business. It was, and to a major extent still is, populated by a large number of fairly small companies that target their products to narrowly defined market niches. Indeed, some products in this survey are niche products. However, the entry of larger companies, such as Analog Devices (ADI), enabled many signal-conditioner users to obtain all the products they needed from a single source.

Now, ADI's historic archrival, Burr-Brown, has entered the fray by developing its own line of signal conditioners that includes units that are pin-compatible with ADI's 5B series. Meanwhile, ADI has not been resting on its laurels. It has introduced the 6B series of digital-output signal conditioners. These units store configuration data in nonvolatile memory and produce RS-422/RS-485-compatible outputs. The firm is also about to begin offering the 7B series—units that are smaller than the 5Bs, utilize a higher supply voltage, and satisfy many requirements in process instrumentation.

Filters appear in signal-conditioner garb

Meanwhile, the success of the 5B series has encouraged at least one company to offer products that complement rather than compete with those supplied by ADI, Burr-Brown, and others. Frequency Devices, a vendor of active filters, recently announced 9-pole Bessel and Butterworth lowpass antialiasing filters in the 5B form factor. The availability of these filters—which offer cutoff frequencies from 1 to 50 kHz—enhances a system designer's ability to use 5B-style signal conditioners for processing dynamic data, for example, in analysis of acoustic and mechanical systems.

Don't get the impression, though, that all the news in signal conditioning is being made by Analog Devices, Burr-Brown, and companies that employ their packaging approaches. Vendors large and small have been making innovations as well. Within the past year, Beckman Industrial Corp, an affiliate of diversified corporate giant Emerson Electric, introduced the 8000 series, a signal-conditioning line which, besides offering technical innovations, takes advantage of a distribution method that is unusual in this product area—the prod-

Though similar in appearance to many vendors' signal-conditioner families, these modules from Measurement Technology are compatible only at the manifold level because their pinout and insulated hold-down mechanism are designed to let you safely plug and unplug them without removing power or high common-mode-voltage signals.

Signal conditioners, mounted singly or in groups close to the transducers, can have analog or digital system interfaces.

ucts are available through Beckman Industrial's distributors. Heretofore, signal-conditioning vendors have generally shied away from selling through distributors because the large number of variations within a model type could create an inventory nightmare for resellers. By internally modularizing the products and simplifying the configuration process, Beckman Industrial feels that it has licked the inventory problem.

Though you might think of the internal modularity of Beckman Industrial's signal conditioners as strictly a packaging issue that has little technical significance, it is but one of a number of packaging-related subjects that are quite important in the signal-conditioning business. For example, most of the signal conditioners discussed here differ from process-variable transmitters in the degree of environmental hardening inherent in their packaging. Signal conditioners' electrical design permits them to withstand many of the rigors of a factory environment, but unlike transmitters, signal conditioners are not enclosed in explosion-proof, or even drip-proof, housings.

Views on encapsulation differ

A unit's enclosure can tell you not only about the intended application but often also about the designer's philosophy, and maybe something about the vendor's history. Packages range from open cards that plug into rack adapters, to units that resemble electromechanical relays and plug into relay sockets, to small, enclosed modules—both encapsulated and unencapsulated. Some of these units require no sockets; they have screw terminals on them that accept the "field

Transducers—the variety is almost endless

In the process industries, the most common physical quantities that signal conditioners monitor are temperature, pressure, flow, and liquid level. In automatic test systems in electronics, temperature measurement is also common, but the range of signals and transducer types is much wider. A full treatment of transducers and their most important characteristics is clearly beyond the scope of a single magazine article, but a brief discussion of the operation of a few of the most common types is appropriate. (A good place to gather detailed information about transducers is in *Sensors Magazine and Buyers' Guide* (Peterborough, NH).)

Thermocouples are the most common sensors. Their output voltages are typically a few millivolts and they require cold-junction compensation to correct for variations in the signal conditioner's temperature. Thermocouples' response to temperature variations is somewhat nonlinear. Some signal conditioners correct for the nonlinearity; others leave that task for software running on the computer that controls the data-acquisition system.

Thermocouples are physically frail and are subject to wire breakage or breakage at the point where the two dissimilar metals that comprise the couple are welded together. As a consequence, most thermocouple signal conditioners are designed to sense an open input and to produce an end-scale output under open-input conditions. If you are using the conditioned thermocouple output as an input to a control system, you probably want to be able to select whether the signal conditioner treats an open input as a positive or a negative full-scale signal. Most thermocouple signal conditioners let you make this choice. Despite their shortcomings, thermocouples remain popular because of their simplicity, small size, and low cost, and because they require no excitation voltage.

Resistance-temperature detectors (RTDs) are another popular type of temperature transducer. As their name suggests, RTDs take advantage of the temperature-dependent resistance variation of a metal—usually platinum. Signal conditioners often measure an RTD's resistance by placing the device in a bridge circuit or by forcing a constant current through it and measuring the voltage across it. RTDs therefore require excitation.

Another common type of transducer is the strain gauge. Like RTDs, strain gauges take advantage of the resistance change of metal, except that in strain gauges the change occurs because of elongation or strain rather than because of a temperature change. Strain gauges are usually connected in bridge circuits and hence, like RTDs, require excitation.

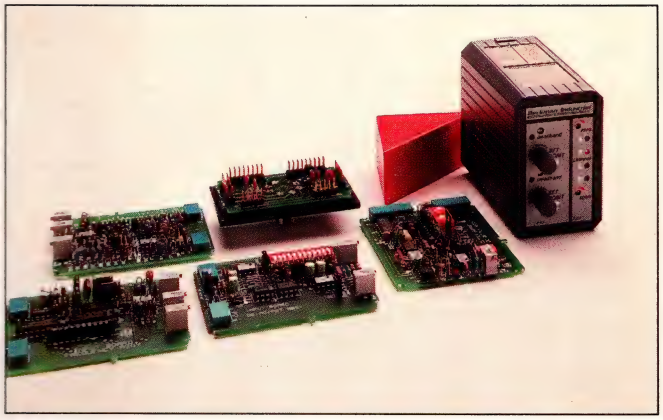
Strain gauges form the heart of several types of transducers.

wiring" to and from the data-acquisition system and the transducers. You must mount other units in individual sockets, which include field-wiring terminals, or on backplanes, which accommodate groups of modules in addition to the field wiring. Some vendors call their backplanes "manifolds."

Some manifolds incorporate power supplies for the signal-conditioning modules; others require you to mount a power supply separately. On manifolds, screw terminals are common for transducer connections, but connectors often carry the signals to the data-acquisition system.

The philosophy of how to handle field wiring is not a small issue in signal conditioning. For example, most vendors favor screw terminals over connectors for sig-

Text continued on pg 142



By incorporating internal modularity, Beckman Industrial has made its 8000 series configurable by distributors, making possible delivery times of a few days in a field where 6-week deliveries are not uncommon.

For example, you can obtain strain-gauge-based transducers that measure pressure, force, and displacement. Load cells, which measure weight, are usually strain-gauge-based force transducers.

There are a variety of inductive transducers, the most common of which are linear variable displacement transformers (LVDTs) and their rotary counterparts (RVDTs). As their name suggests, LVDTs measure linear displacement. LVDTs and RVDTs require ac excitation, usually at a moderate audio frequency such as 2.4 kHz.

Contacts act as transducers

Though not commonly thought of as transducers, electromechanical relay contacts commonly become signal sources for data-acquisition systems. Naturally, if the only function a contact performs is to supply a signal to a data-acquisition system, you may not have to condition the signal at all, though you may want to debounce it. However, unless your relay has contacts made of an alloy intended for dry-circuit applications, you may need to excite the contact with a voltage of perhaps 24V, which is much too high to form a safe input for a TTL circuit. You may also want to monitor the status of a contact that actually switches high ac or dc voltages to a load. Any of these situations dictates the use of a contact-sensing signal conditioner. For safety, such signal conditioners should include isolation.

A feature touted by a number of signal-conditioner vendors is the ability to mix analog and digital signal conditioners in the same manifold. Here, "digital" does not refer to modules that produce digital representations of analog variables (for example RS-485-compatible outputs from a thermocouple signal conditioner). Rather, it refers to contact-status-sensing signal conditioners and to signal conditioners that accept logic-level inputs *from* a data-acquisition system and provide isolated, medium-power, switched outputs (for example, triacs, SCRs, and relays).

There is yet another class of signal conditioner—one that *accepts* a digital representation of an analog variable from a computer system and supplies an analog output voltage or current to control, for example, a valve-positioning servomechanism. Clearly, D/A converters are at the heart of such signal conditioners, but, usually, the units include much more. Generally, they incorporate isolated, medium-power, output amplifiers with protection against overvoltage and overcurrent; dc/dc converters to supply power to these amplifiers; and often UARTs (universal asynchronous receiver/transmitters) to convert serial data received from the computer system to parallel form.

TABLE 1—REPRESENTATIVE SIGNAL CONDITIONERS

VENDOR	MODEL OR SERIES	FUNCTIONS	US PRICE	ISOLATION	OUTPUT	ACCURACY	SIZE	REPAIRABLE	ADJUSTMENTS	COMMENTS
ACROMAG	1800	INPUT MODULES WIDEBAND mV/V PROCESS CURRENT THERMOCOUPLE RTD SLIDEWIRE FREQUENCY AC CURRENT AC VOLTAGE PNEUMATIC BRIDGE EXCITATION FILTER V/I OUTPUT 4 TO 16 CHANNEL CAGES POWER SUPPLIES	 $205 $185 $210 $210 $190 $265 $205 $190 $285 $155 $60 $190 $150 TO $295 $295	250V AC	ALL INPUT MODULES: (SPEC AT PURCHASE) 0 TO 1V 0 TO 5V 0 TO 10V 4 TO 20 mA BIPOLAR RANGES (FOR EXAMPLE ±5V) WHERE APPLICABLE	MOST UNITS: 0.1% OF SPAN AC INPUT: 0.5% OF SPAN	MODULES: 1x3.45x 4.90 IN. CAGES VARY POWER SUPPLIES: 4.1x5.25x 5.5 IN.	RETURN TO VENDOR RECOMMENDED	POTENTIOMETERS, JUMPERS, SELECTED RESISTORS	VENDOR ALSO OFFERS THE 4000 SERIES, WHICH HAS A μCOMPUTER ON THE BACKPLANE. THESE SYSTEMS TRANSMIT OUTPUTS IN ENGINEERING UNITS TO A HOST SYSTEM VIA RS-232C OR RS-485, PRICING FOR A TYPICAL CONFIGURATION (8 ANALOG AND 8 DIGITAL INPUTS): $1982.
ACRO-SYSTEMS	ACRO-900	12-BIT ADC 17-BIT ADC PULSE COUNTING DIGITAL I/O THERMOCOUPLE RTD STRAIN GAUGE LVDT/RVDT pH/ION ACTIVITY	$1595 $1750 $1050 $1350 $1350 $1475 $1375 $1750	100V PEAK	RS-232C/ RS-485/ RS-422	DEPENDS ON FUNCTION. USUALLY ±0.1%	5.2x1.7x14 IN.	YES	BY SOFTWARE	
ACTION INSTRUMENTS	4380	WIDE-RANGE DC INPUT; 30 USER-SELECTED V AND I RANGES	$315 (1 TO 9)	1000V DC OR PEAK AC	19 USER-SELECTED V AND I RANGES	±0.1% OF SPAN	2x2.8x3.5 IN.	RETURN TO VENDOR	DIP SWITCHES POTENTIOMETERS	RED/GREEN DIAGNOSTIC LED INDICATES POWER STATUS AND INPUT'S APPROXIMATE PERCENTAGE OF RANGE.
ANALOG DEVICES	3B	26 INPUT AND 2 OUTPUT TYPES. THERMOCOUPLE, STRAIN GAUGE, RTD, LVDT, AC VOLTS, FREQUENCY INPUT 16-, 8-, 4-SLOT MANIFOLDS, POWER SUPPLIES	$84 TO $222 (100)	1500 PK ON 1 OUTPUT AND 18 INPUT UNITS. NONE ON 8 INPUT AND 1 OUTPUT UNITS	±10V AND 4 TO 20 mA ON INPUT MODULES 4 TO 20 mA ON OUTPUT MODULES	TOTAL UNADJUSTED ERROR: ±1%	3.15x 0.775x 3.395 IN. MANIFOLDS AND POWER SUPPLIES VARY	YES	POTENTIOMETERS	BACKPLANES HAVE LEDs TO INDICATE POWER-SUPPLY STATUS.
	5B	9 INPUT AND 1 OUTPUT TYPES. NARROW- AND WIDEBAND DC mV, V, PROCESS I, THERMOCOUPLE, RTD, RESISTIVE BRIDGE INPUTS. 16-, 8-, 4-SLOT MANIFOLDS, POWER SUPPLIES	$105 TO 150 (100)	1500V CONTINUOUS	±5V OR 0 TO 5V ON INPUT MODULES. 4 TO 20 mA ON OUTPUT MODULES	±5% OF SPAN UNADJUSTED TOTAL ERROR	2.25x2.25 x0.6 IN. MANIFOLDS AND POWER SUPPLIES VARY	NO	NONE	
	6B	3 INPUT AND 1 OUTPUT TYPES. HANDLE mV, V, mA, RTD INPUTS 1-, 4-, 16-SLOT BACKPLANES, POWER SUPPLIES	$140 (100)	1500V CONTINUOUS	ON INPUT UNITS: ASCII RS-232C/ RS-485. ON OUTPUT UNIT: 4-TO-20 mA	DEPENDS ON UNIT. FROM 0.03 TO 2% MAX	2.3x3.1x 0.75 IN.	NO	SOFTWARE-CONFIGURABLE SPAN RANGE, ADDRESS	
BECKMAN INDUSTRIAL	8000	STRAIN GAUGE, RTD, LVDT, THERMOCOUPLE, PULSE INPUT	$225 TYP 1 UNIT	1500V DC OR PEAK AC	ORDER WITH V, I, OR FREQUENCY OUTPUT	DEPENDS ON UNIT. SPECS COVER STABILITY LINEARITY	2.01x3.7x 3.2 IN.	YES	POTENTIOMETERS, INTERNAL JUMPERS, DIP SWITCHES	DISTRIBUTORS CAN BUILD AND CALIBRATE OVER 650 TYPES TO YOUR SPECS USING MODULES IN STOCK.
BLH	5510/5570	STRAIN GAUGE (WEIGHT, FORCE, PRESSURE)	$473	SEE COMMENT	0 TO 10V, 0 TO −10V. 4 TO 20 mA 0 TO 20 mA	NONLINEARITY 0.2% OF RANGE	1.4x5x6.8 IN. 5.25-IN. RACK HOLDS 10	YES	POTENTIOMETERS	UNITS ARE ON EUROCARDS, RACK IS AC POWERED. MODULE INCLUDES ADJUSTABLE ALARM SETPOINTS. ISOLATE USING SEPARATE UNIT BETWEEN TRANSDUCER AND SIGNAL CONDITIONER.

TABLE 1—REPRESENTATIVE SIGNAL CONDITIONERS (continued)

VENDOR	MODEL OR SERIES	FUNCTIONS	US PRICE	ISOLATION	OUTPUT	ACCURACY	SIZE	REPAIR-ABLE	ADJUST-MENTS	COMMENTS
BURR-BROWN	SCM5B	5 INPUT UNITS EACH WITH MANY OPTIONS: WIDE/ NARROW-BAND mV, V, THERMOCOUPLE, POWER SUPPLY, 16-SLOT MANIFOLD	$150 (1 TO 24)	1500V RMS	±5V OR 0 TO 5V	±0.02% NONLIN-EARITY	2.26×2.26 ×0.6 IN.	NO	NONE	VENDOR ALSO OF-FERS ISOLATED DIGITAL OUTPUT AND INPUT MOD-ULES. THE 1.25×1.7 ×0.5-IN. UNITS SELL FOR $8.50 TO $10.50.
CALEX	160 SERIES AND MOD-EL 465	STRAIN-GAGE CONDITIONERS (NARROW- AND WIDEBAND)	$70 TO $245 (1 TO 9)	ISOLATED AND NON-ISOLATED UNITS	±10V	ERROR COMPONENTS SEPARATELY SPECIFIED	MANY ON 4×2.5-IN. CARDS	MOST UNITS, NO	POTENTIO-METERS; 1 UNIT USES SWITCHES	MOST UNITS POW-ERED FROM ±15V DC. AC-POWERED UNIT ALSO. VENDOR OFFERS HARDWARE TO MOUNT ALL UNITS.
	470	THERMOCOUPLE AMPLIFIER	$175	NON-ISOLATED	±10V	SEE ABOVE	2.75×2× 2.87 IN.	NO	POTENTIO-METERS	AC LINE-POWERED UNIT.
	176 AND 178	INSTRUMENTATION AMPLIFIERS	$69 TO $112	NON-ISOLATED	±10V	NONLINEAR-ITY 0.005%	1.52×1.52 ×0.7 IN.	NO	EXTERNAL	
CAPACITEC	4000 SERIES	SPECIALIZED AMPLIFIERS THAT EXCITE CAPACIT-IVE TRANSDUCERS AND DEMODULATE THEIR OUTPUTS. 4-, 8-, AND 16-CHANNEL RACK ADAPTERS	CARDS FROM $675 ADAPT-ERS: $1470 TO $2370	NOT APP-LICABLE	0 TO 10V	REPEAT-ABILITY: ±0.01%	MODULES: 6.3×3.17× 1 IN. RACK ADAPTERS: 3.5 IN. HIGH; 5 TO 19 IN. WIDE	YES	POTENTIO-METERS	PRIMARY APPLICA-TION IS CAPACITIVE DISPLACEMENT TRANSDUCERS. ALSO USABLE WITH SOME INDUCTIVE TRANSDUCERS.
DGH	D1000 AND D2000 SERIES	APPROXIMATELY 80 TYPES: V AND I, ACCUMULATOR, BRIDGE, PULSE, RTD, FREQUENCY, THERMOCOUPLE, EVENT, DIGITAL I/O	$250 TO $325 (1 TO 9)	500V RMS	RS-232C/ RS-485 ASCII	±0.02% GAIN AND NONLINEAR-ITY ERRORS	3.6×2.86× 0.85 IN.	YES	PERFORM-ED WITH SOFTWARE. STORED IN NONVOLA-TILE RAM	VENDOR ALSO SUPPLIES UNITS WITH 4 TO 20 mA OUTPUTS IN SIMI-LAR ENCLOSURE. USES NO MANI-FOLDS. TERMINAL BLOCK PLUGS ONTO MODULE. UNITS RECEIVE UNREGU-LATED 10 TO 30V DC POWER.
DUTEC	VARIOUS	20 MODELS FOR V AND I, THERMO-COUPLE, RTD AND SEMICONDUCTOR TEMPERATURE SENSORS. MANIFOLDS AND POWER SUPPLIES	$70 TO $110 (QTY 1)	1500V RMS	TTL-LEVEL PULSES WHOSE 14.4- TO 72-kHz FREQUENCY REPRESENTS ANALOG VARIABLES	±0.5% OF RANGE GAIN AND OFFSET ERRORS. ±0.1% LIN-EARITY (BEST STRAIGNT LINE)	1.7×1.25× 0.6 IN.	NO	NONE	UNITS CONFORM TO INDUSTRY STAN-DARD PINOUT AND SIZE OF DIGITAL I/O MODULES, WHICH THE VENDOR ALSO SELLS. BACKPLANES ARE COMPUTER BASED AND COM-MUNICATE WITH A HOST VIA RS-232C.
ECTRON	563HN	WIDE RANGE OF TRANSDUCERS IN-CLUDING THERMO-COUPLES AND DC-EXCITED BRIDGES, AC-POWERED RACK ADAPTERS	$665 (1 TO 100)	NONE BUT WITH IN-PUT AT-TENUATOR ±300V	±10V	NONLINEAR-ITY 0.005% FULL SCALE OF BEST STRAIGHT LINE THRU ZERO	5.25×0.9× 8 IN. 19-IN.-WIDE ADAPTER HOLDS 16 UNITS	YES	POTENTIO-METERS; USER ADDS BRIDGE-COMPLET-ION RES-ISTORS	VENDOR SUPPLIES MANY SERIES OF SIGNAL CONDI-TIONERS FOR AUTOMOTIVE, AIR-BORNE, INDUSTRI-AL, MARINE, AND NUCLEAR APPLI-CATIONS.
GOULD	20-4615 SERIES; 57-1301-00	5 MODELS-UNITS FOR RESISTIVE AND INDUCTIVE TRANSDUCERS AND GENERAL-PURPOSE WORK	$795 TO $1950	2 UNITS HAVE 500V ISOLATION	5V	±0.1% OF FULL SCALE	6.1×2.2×13 IN. MANIFOLDS HOLD 8	YES	ON FRONT PANEL. ONE UNIT IS COMPUTER PROGRAM-MABLE	
KISTLER	5011A1	CHARGE AMPLIFIER USED WITH PIEZO-ELECTRIC TRANS-DUCERS FOR EXAMPLE, ACCELEROMETERS	$2000 TO $2400	NOT APPLIC-ABLE	±10V	±1% OF FULL SCALE	3.7×7.7×6 IN. WITH CASE	YES	DIGITAL CONTROL FROM VIA IEEE-488 OR FROM PANEL	
KYOWA DENGYO	MCC SERIES	6-, 8-, AND 16-CHANNEL ASSEM-BLIES. 14 TYPES OF SIGNAL CONDITIONERS	$3890 6 CHAN-NEL; $5400 16 CHAN-NEL	NOT SPECIFIED	±30 mA OR ±5V (DE-PENDS ON CONDITION-ER TYPE)	NOT SPECIFIED	5.25-IN. HIGH. 16-CHANNEL UNIT IS 19-IN. WIDE	YES	POTENTIO-METERS AND SWITCHES	PRIMARY APPLICA-TION IS WITH VEN-DOR'S MAGNETIC (TAPE) ANALOG DATA-RECORDING SYSTEMS.

A unit's enclosure can tell you not only about the intended application but also about the designer's philosophy, and maybe something about the vendor's history.

TABLE 1—REPRESENTATIVE SIGNAL CONDITIONERS (continued)

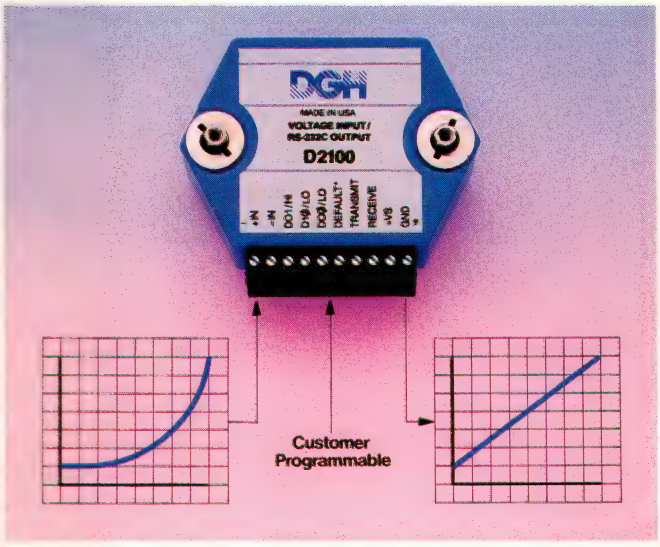
VENDOR	MODEL OR SERIES	FUNCTIONS	US PRICE	ISOLATION	OUTPUT	ACCURACY	SIZE	REPAIRABLE	ADJUSTMENTS	COMMENTS
MEASUREMENTS GROUP	2200 SYSTEM	HIGH-GAIN WIDEBAND AMPLIFIER WITH EXCITATION SOURCE AND SELECTABLE FILTER	$1190 PLUS ENCLOSURE	350V DC OR PEAK AC	±10V AND 1V RMS	NONLINEARITY 0.01% OR FULL SCALE	7x1.71x15.9 IN.	YES	SWITCHES, POTENTIOMETERS ON PANEL AND INSIDE	1- AND 4-CHANNEL PORTABLE AND 10-CHANNEL RACK-MOUNTED ENCLOSURES.
MEASUREMENT TECHNOLOGY	SC200 SERIES	6 INPUT UNITS NARROW/WIDEBAND mV, V, I, RTD, THERMOCOUPLE, V, I OUTPUT UNITS. 1-, 8-, AND 16-SLOT NONMULTIPLEXED BACKPLANES, 16-SLOT MANIFOLD (MULTIPLEXED)	$85 (100) 16-CHANNEL BACKPLANE $250 AND $260	1500V RMS	INPUT UNITS: ±5V	FACTORY ADJUSTED TO 0.05%	2.55x3.1x0.7 IN.	NO	SOME UNITS HAVE JUMPERS FOR CONFIGURATION	VENDOR CLAIMS UNITS CAN BE REPLACED SAFELY WITHOUT REMOVING POWER OR TRANSDUCER CONNECTIONS. SEE ARTICLE TEST.
METRABYTE	M2000 SERIES	30 V, I, BRIDGE PULSE AND FREQUENCY INPUT UNITS. OUTPUTS IN ENGINEERING UNITS	$275 TO $350	500V RMS 60 Hz	RS-232C OR RS-485 (RESOLUTION =15 BITS)	±0.2% GAIN ERROR ±0.01% NONLINEARITY	3.6x2.45x1.1 IN.	NOT SPECIFIED	PERFORMED WITH SOFTWARE, STORED IN NONVOLATILE RAM	VENDOR OFFERS SEVERAL SERIES. M1000 SERIES DOES NOT SCALE OUTPUTS IN ENGINEERING UNITS. M3000/M4000 SERIES PROVIDE PROCESS V/I OUTPUTS.
PHOENIX CONTACT	MCR MODULES	250 KINDS COVER MOST TRANSDUCER TYPES FOUND IN INDUSTRY, ADCs, POWER SUPPLIES	$150 TO $750	SOME TYPES USE OPTICAL ISOLATION	VERSIONS 0 TO 20 mA 4 TO 20 mA 0 TO 10V	0.1% GAIN ERROR	3.1x3.37x1 IN.	RETURN TO VENDOR	POTENTIOMETERS	ALL UNITS, INCLUDING POWER SUPPLIES, MOUNT ON DIN RAILS. HENCE MANIFOLDS ARE UNNECESSARY.
PRESTON SCIENTIFIC	8300AU	WIDEBAND, HIGH-GAIN INSTRUMENT AMPLIFIER SYSTEM WITH EXCITATION, FILTER, AND PROGRAMMABLE FUNCTIONS	$5750 (2 AMPLIFIERS) $950/CHANNEL	350V DC OR PEAK AC	±10V A SECOND UNFILTERED ±10V OUTPUT IS OPTIONAL	GAIN 0.1% 0.01% OPTIONAL. NONLINEARITY 0.01% OF RANGE	16 MODULE UNIT: 19x 10.5x22.5 IN.	YES	SWITCHES, POTENTIOMETERS	ALL FUNCTIONS ARE PROGRAMMABLE FROM THE PANEL. IEEE-488, OR RS-232C PROGRAMMING AVAILABLE.
SCHAEVITZ ENGINEERING	SMS	LVDT SIGNAL CONDITIONERS	$205	NOT APPLICABLE	±10V	0.1% NONLINEARITY	2x2.45 IN.	YES	USER SUPPLIED	PRIMARILY FOR OEM APPLICATION.
	LPM	LVDT SIGNAL CONDITIONERS	$313	NOT APPLICABLE	±10V	SAME	5x3.5 IN.	YES	OPTIONAL POTENTIOMETERS	
	SYS96	LVDT SIGNAL CONDITIONERS	$2880 (8 CHANNELS)	NOT APPLICABLE	PLACES DATA ON IBM PC BUS	0.5% NONLINEARITY	IBM PC I/O CARD	YES	VIA SOFTWARE	CARDS HAVE 8, 16, OR 24 CHANNELS. ONE PC CAN CONTAIN 96 CHANNELS.
SCHLUMBERGER INDUSTRIES	910XXX SERIES 911XXX SERIES	SINGLE AND MULTICHANNEL TRANSDUCER CONDITIONERS	$280 (1 CHANNEL)	NOT APPLICABLE	±5V, ±10V, ±20 mA, DEPENDS ON MODEL	0.1% NONLINEARITY	1 CHANNEL 1.2x2.4x <5 IN.	YES	POTENTIOMETERS	VENDOR OFFERS MANY LVDT CONDITIONERS. MULTICHANNEL UNIT USES IEEE-488. AN IBM PC BUS LVDT CONDITIONER SELLS FOR $1500.

nal conditioners' transducer connections because an electrician can install the wiring using only a wire stripper and a screwdriver; electricans don't customarily carry soldering irons or crimping tools. But if the screw terminals are on the signal-conditioning module itself and the module needs to be replaced, service personnel must disconnect all of the wires individually. Unless they carefully tag each wire before exchanging a module, installers are likely to cross the wires, possibly damaging the transducer or the signal conditioner. This aspect of field wiring has led to the popularity of socketing signal-conditioning modules or of using screw-terminal strips that, themselves, plug onto the signal conditioner or the manifold.

Wiring is a central issue

Indeed, wiring considerations are so important to the signal-conditioning field that they dominate the thinking of signal-conditioner designers. For example, many modules incorporate multiplexers. If a module has a low-impedance, voltage-source analog output that acts as an open circuit until the module receives an output-enable signal, a single wire or pair of wires can carry the outputs of a large number of modules. If each module responds to a unique address that you can program with jumpers or switches, and if you send the output-enable signal in the form of a serial bit stream that all of the modules receive and decode, you need no more than one additional wire pair to communicate with perhaps thousands of modules. Of course, such multiplexing schemes can sacrifice speed for wiring simplicity. Furthermore, in the scheme described, unless the wiring runs from module to module, rather than from each module back to a central point, there will be no savings in wiring cost.

In process control, the 4- to 20-mA analog-output range has become a standard for transmitters and signal conditioners. Years ago, designers of process instrumentation adopted a current-output rather than a voltage-output standard for such devices. One reason for this change is that if you have a voltage-output device and a wire carrying the output signal breaks, even if a value of zero is out of range (as it would be with a range of, say, 1 to 5V), you might wait a long time before the signal level reached a value indicative of an open connection. With high-input-impedance receivers sensing the signal conditioners' output voltage, charge stored in the wiring capacitance could take an unacceptably long time to dissipate. Substituting low-input-impedance receivers could cause IR drops in the wiring sufficient to excessively degrade accuracy. In a current-based design, open wires are much less likely to cause failures that go undetected.



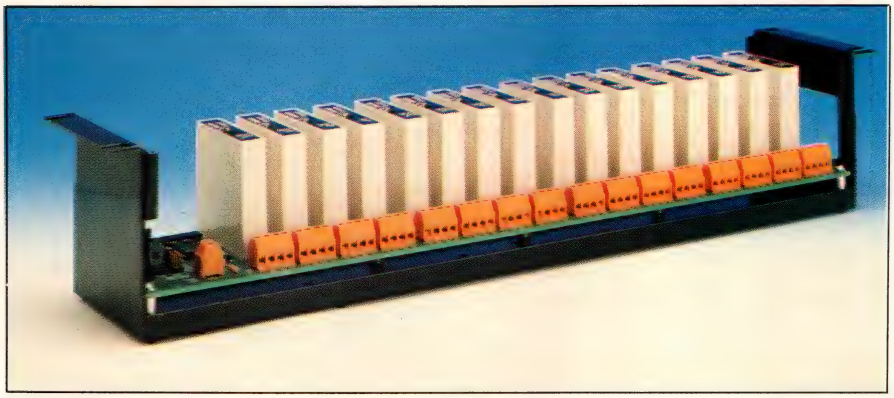
The advantages of digital techniques show up in this DGH module. You can use an RS-232C interface to send codes that alter the unit's characteristics. It stores its configuration in nonvolatile memory.

A signal conditioner need not have a voltage output to operate in a multiplexed mode similar to that described above; multiplexed 4- to 20-mA outputs are possible. In this case, an unselected device on the loop must act as a short circuit, or at least as a low impedance, and all of the current sources around the loop should have very high output impedances.

Analog outputs still predominate

Now that most of the world has gone digital, you might be tempted to ask why so many signal conditioners continue to offer analog outputs. Though tradition and inertia probably play a role, the difficulty of establishing a widely accepted standard apparently plays an even greater role. At present, manufacturers of signal conditioners with digital outputs do not appear to have reached a concensus on a communications protocol. Indeed, enough characteristics are unique to specific application areas (for example HVAC—heating, ventillating, and air conditioning) that a strong rationale seems to exist for multiple protocols. Several manufacturers have introduced digital-output signal conditioners, and the marketplace must decide which, if any, of their protocols will emerge as standards.

Unlike transmitters, signal conditioners are not enclosed by their vendors in explosion-proof, or even drip-proof, housings.



A standard 19-in. rack can accommodate signal conditioners like these SCM5B units from Burr-Brown. This 3½-in.-high manifold can hold 16 units. Note the screw-terminal blocks, which require no preparation of wire ends other than stripping and twisting.

Norm Bernstein, architect of ADI's 6B series of digital-output signal conditioners, says, "I'd like customers to view the use of digital techniques in these modules as a means of correcting the shortcomings of analog electronics rather than as a vehicle for creating a new output standard. We even thought about converting from digital to analog just ahead of the module outputs so that users could have a familiar interface that they've dealt with for years. But at the time we designed the 6B units, we couldn't justify an analog output economically, especially when we thought about how many users would have to convert it to digital form."

The digital techniques embodied in the 6B modules and others, such as the D1000 and D2000 series from DGH, pay strong dividends in one area in particular:

Combining two circuit-module types in one unit, Calex's signal conditioner for resistive bridges includes an ac-line-operated power supply and incorporates screw terminals for field wiring.

configuring the modules for a specific application. Setting the scale factor and offset of modules in ADI's very successful analog-output 5B series—to obtain results in engineering units, for example—requires laser trimming of resistors, an operation that, clearly, only the factory can perform. Because the vendor stocks the modules in depth, if you are ordering a standard version, you can probably obtain it in a few weeks. Custom variations can take 12 weeks, however. With the 6B units, by using a PC and the utility software that accompanies the modules, you can set the scale factor and offset yourself. Therefore, the vendor need not stock as many varieties; the result is economies of scale.

Digital techniques also permit elimination of trimming potentiometers. Though the opinion is far from unanimous, many EEs consider the use of potentiometers an anathema in a factory environment. For one thing, potentiometer settings can shift as a result of vibration. Secondly, most of the devices are not amenable to encapsulation, and, except for sealed devices (many of which are quite expensive), it is advisable to keep potentiometers away from grimy and corrosive atmospheres. Furthermore, especially if a unit has several potentiometers, if someone disturbs the settings, you may never be sure that you have readjusted the potentiometers to their original values. When D/A converters and nonvolatile memories replace potentiometers, if the software permits, you can store the potentiometer settings. As long as the computer and the disk with the setup file are handy, you can get back to where you started from.

Analog outputs are faster than digital

However, digital-output signal conditioners are not for every application. Most of them use ADCs based on voltage-to-frequency conversion. Converters of this

Manufacturers of signal conditioners

For more information on signal conditioners such as those described in this article, circle the appropriate numbers on the Information Retrieval Service card or use EDN's Express Request service. When you contact any of the following manufacturers directly, please let them know you saw their products in EDN.

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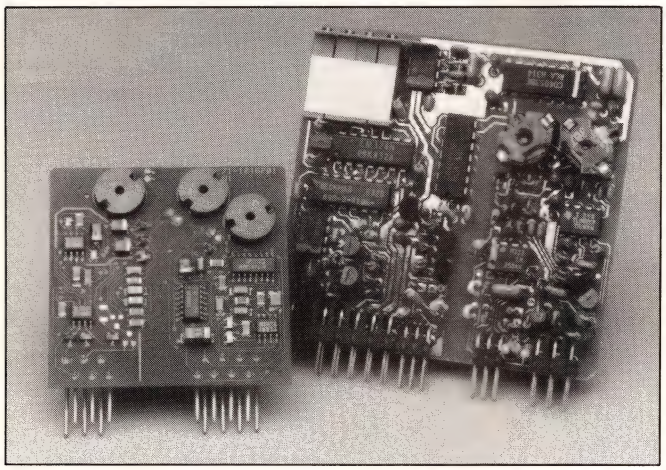
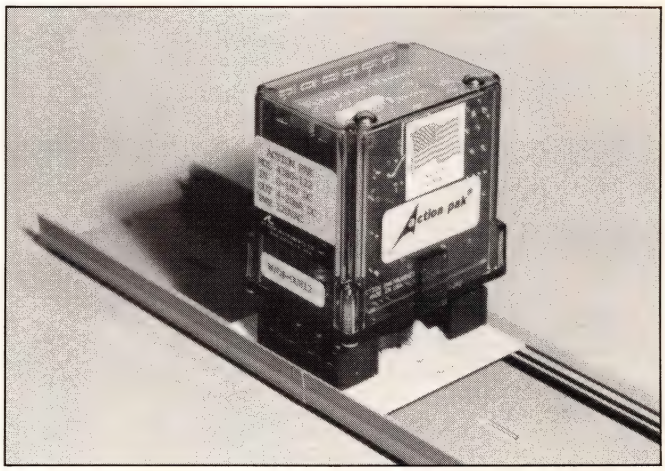
Leisurely conversion speeds are adequate in many industrial applications, but in production testing and vibration analysis, you need fast settling and wide bandwidth.



The internal construction of these Analog Devices modules (5B series on left; 3B on right) shows the use of ferrite potentiometer-core transformers for isolation and indicates how surface-mount technology made possible the smaller size of the 5B family.



Among the first vendors to offer industrial signal conditioners, Action Instruments packages this unit in a type of case used by industrial relays. The unit plugs into a relay socket. You can snap many sockets into tracks like the one shown.

type are easy to isolate, offer high resolution, and have excellent immunity to noise. These characteristics ideally suit many industrial applications, where noise sources abound. Moreover, the converters' leisurely conversion speeds are entirely adequate in a significant number of industrial applications, where signals change slowly. But in applications such as production testing and vibration analysis, fast settling and wide bandwidth are vital. Here the A/D conversion, digital communications, and even the multiplexed analog-output techniques that have thus far been used in signal condtioners are likely to come up short.

Don't overlook the importance of isolation

Transforming signals into a form acceptable by data-acquisition systems sometimes involves analog-to-digital conversion and usually involves amplification. There is, however, another function that signal-conditioner vendors insist should almost always be involved: isolation. Isolation is a major factor in safeguarding both equipment and personnel from the hazards of high voltage. Particularly when signals are at millivolt or microvolt levels (as are thermocouple outputs, for example), isolation can provide significant benefits in noise rejection. Yet, despite these advantages, at least in the US, vendors insist that they have an uphill battle convincing customers of the need for isolation. Almost everywhere else, the vendors claim, customers take for granted that a signal conditioner will incorporate isolation.

For the most part, the signal conditioners in this survey use isolation techniques described in a previous EDN article (**Ref 1**). Most signal conditioners use magnetic isolation for analog signals and optical coupling for digital signals. These signal conditioners usually also incorporate transformer-isolated dc/dc converters to power internal circuits and, when intended for use with transducers that require it, to provide the excitation. Hence, signal conditioners that contain dc/dc converters usually isolate both their input circuits and their transducer-excitation sources from the incoming power. A common isolation-breakdown voltage is 1500V dc or peak ac. This voltage is more than adequate where the maximum voltage the field wiring can contact under fault conditions is 240V rms.

A few moments spent thinking about isolation and safety in signal conditioners should make it apparent that if signals at dangerously high common-mode voltages are anywhere near a small signal-conditioning module, the mechanical design of the module and its pin configuration can make a large difference in the care an operator must exercise when replacing a module. That thought struck the principals of Measurement Technology Inc (MTI), and when they designed the SC200 series, which physically resembles ADI's 5B series, they intentionally designed the modules to overcome what they saw as shortcomings of the 5B units. The resulting products are compatible with the ADI units only at the manifold level—you can exchange MTI and ADI manifolds, but you can't mix the two vendors' modules within a manifold. MTI claims that an operator can safely insert and remove its modules

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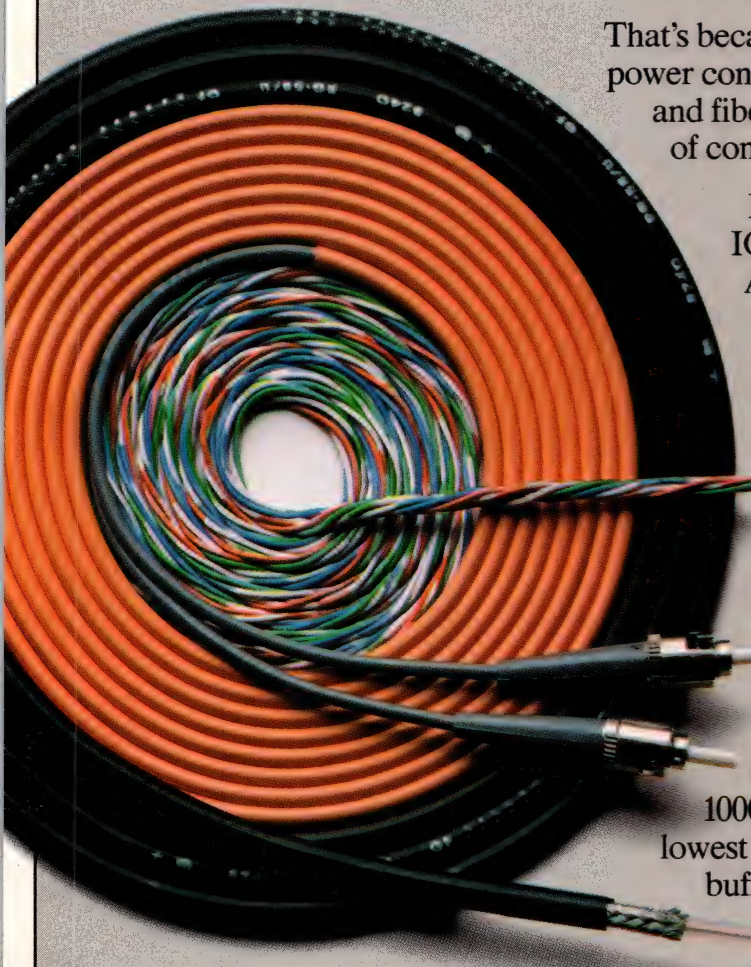

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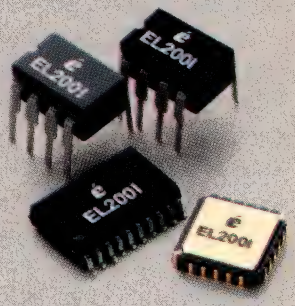

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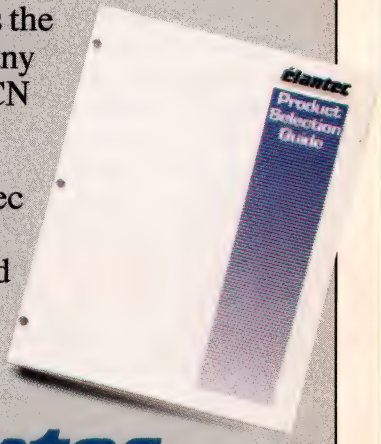

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To calibrate a signal conditioner, you may have to disconnect the transducer and substitute a transducer simulator.

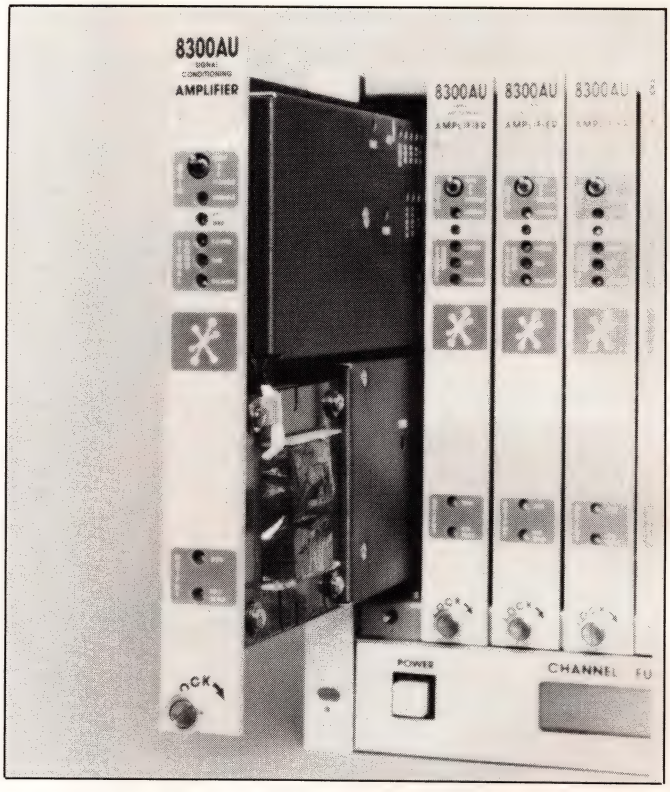
without disconnecting power or signals, and that doing so can't damage a module. Another convenience of MTI's design is the LEDs that tell you which module's multiplexed output is enabled at any instant. To recognize the value of the visual indicator, consider the challenge confronting someone who attempts to locate a problem in a system that contains dozens of modules.

Calibration can be nontrivial

Even if all the modules in a large system are functioning perfectly, calibrating the units can represent a formidable task. The merits of designs that substitute D/A converters for potentiometers were discussed above, but even with units that don't use potentiometers, calibration can be nontrivial. For example, to calibrate a signal conditioner, you may have to disconnect the transducer and substitute a transducer simulator. However, if in response to a command you send, a module can substitute a calibration signal for a trandsucer signal, the calibration process can be much simpler. Furthermore, calibrating a module in this manner prevents you from improperly reconnecting the transducer and possibly damaging it. But, of necessity, such schemes can't calibrate every module part that affects a measurement. With a module that conditions a thermocouple signal, for example, when you substitute a calibration signal for the thermocouple by actuating a solid-state switch within the module, you take the thermocouple connections, with their attendant offsets, out of the circuit. Nulling the offsets caused by the connections can be a major reason for calibrating the signal conditioner.

As long as electronics is used in the measurement and control of physical phenomena, signal conditioning will exist in some form, though advances in transducer design may increasingly place the signal-conditioning function within the transducer. However, because transducers are, by their nature, subject to extreme environmental conditions (conditions in which electronic circuits don't flourish), systems where the electronics and the transducer are separate—as they are with the signal conditioners in this survey—are likely to enjoy continued popularity.

Given the competitive nature of the business, signal-conditioning technology will continue to advance. But, given the conservative nature of the user community, there will be no rush to embrace revolutionary developments. Rather, the stage appears to be set for a continuation of the evolutionary development that has characterized the field. A decade from now, signal conditioners will almost certainly be different from the ones that are popular today, but in all likelihood, the differences will not be so great as to make the products unrecognizable. EDN



The construction of these units from Preston Scientific reveals both their intended application and their ancestry. The fully repairable, programmable modules descend from a long line of amplifiers used in laboratories and aerospace ground-support systems. Older ones had front-panel-mounted operator controls.

Reference

1. Fleming, Tarlton, "Isolation amplifiers break ground loops and achieve high CMRR," *EDN*, December 24, 1987, pg 97.

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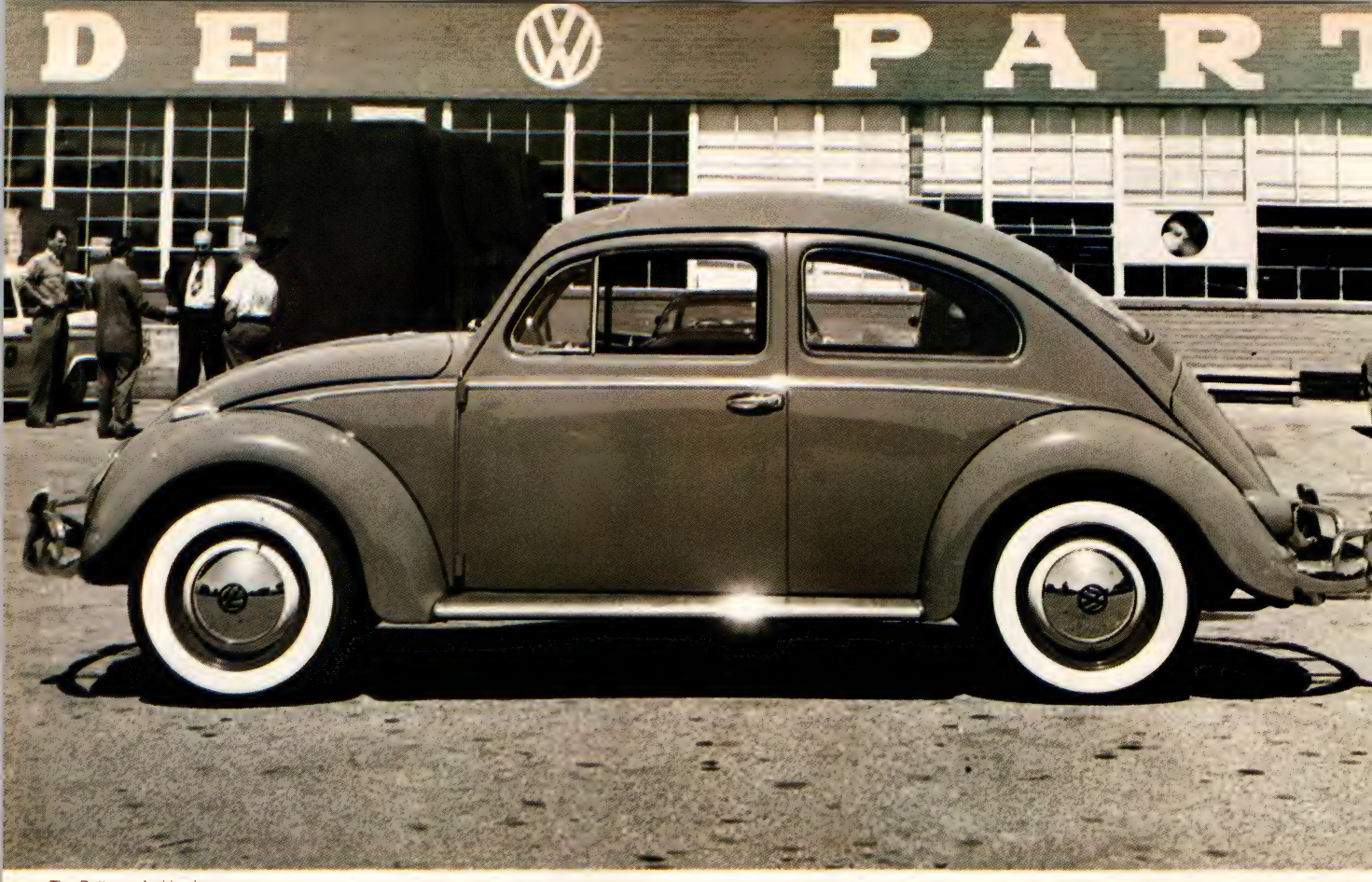

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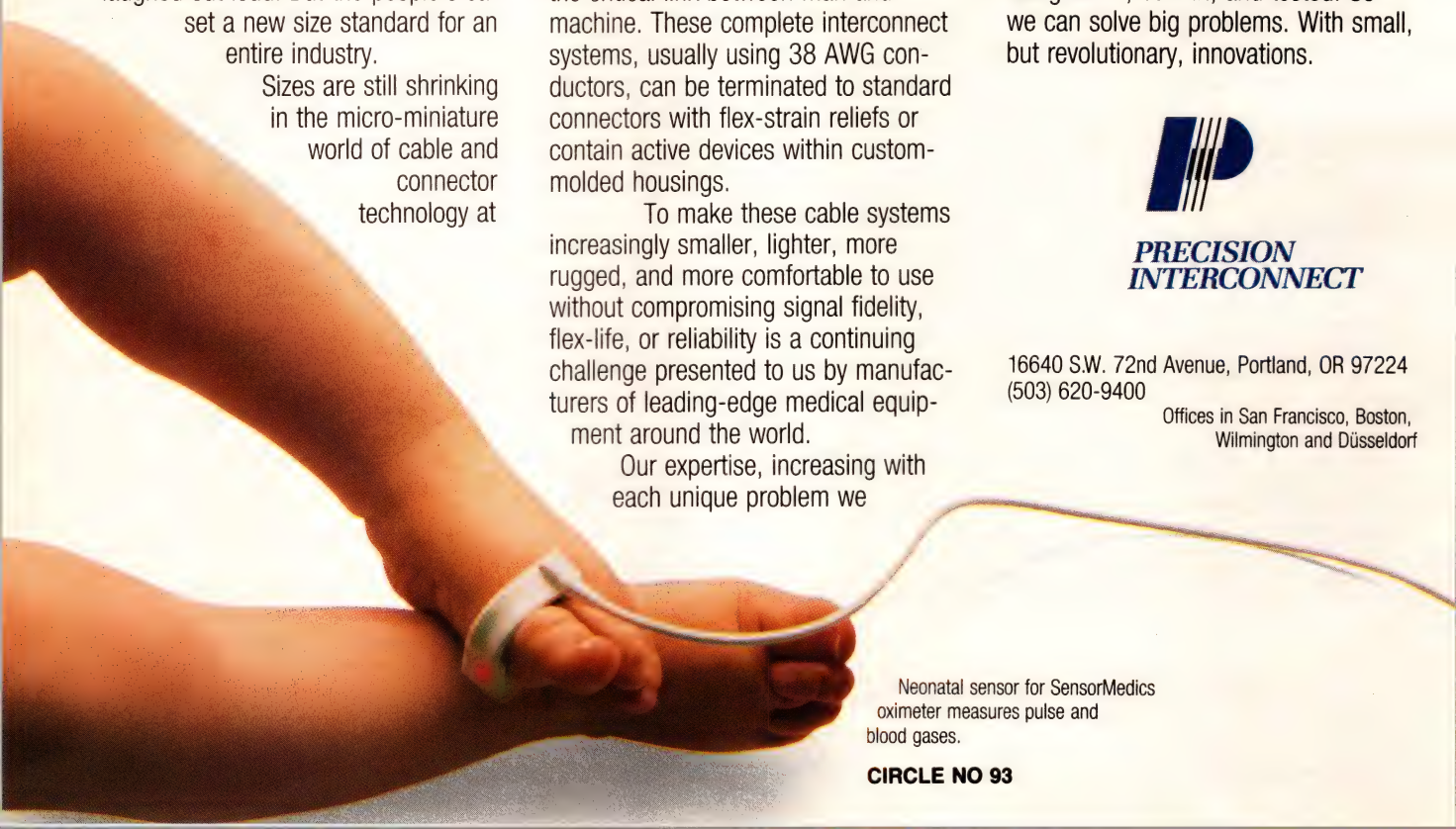

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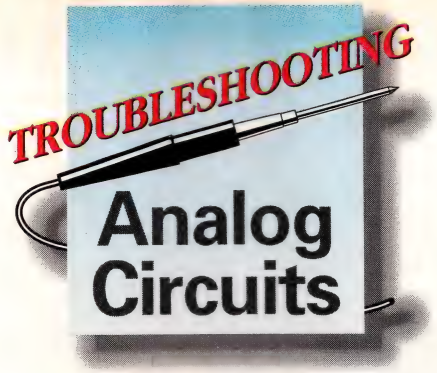


PART 9

Troubleshooting techniques quash spurious oscillations

Oscillations are the ubiquitous bugaboos of analog-circuit design. Not only can you encounter oscillating op amps, as described in part 8, but also oscillating transistors, switching regulators, optoisolators, comparators, and buffers. And, if you think about it, latched-up circuits are just the opposite of oscillating ones, so Bob included them here, too.

Robert A Pease, *National Semiconductor Corp*

Recall the corollary of Murphy's Law that states: "Oscillators won't. Amplifiers will."—oscillate, that is. The knack of spotting and quashing spurious oscillations is, for some fortunate people, a well-developed art. But others have not learned this art well.

I obviously cannot tell you how to solve every kind of oscillation problem. But, I will give you some general principles and then notes on what can go wrong with various components, including comparators and buffers. This information along with a few suggested procedures and recommended instruments will get you off to a good start.

Here are some of the types of oscillations that can pop up unexpectedly:

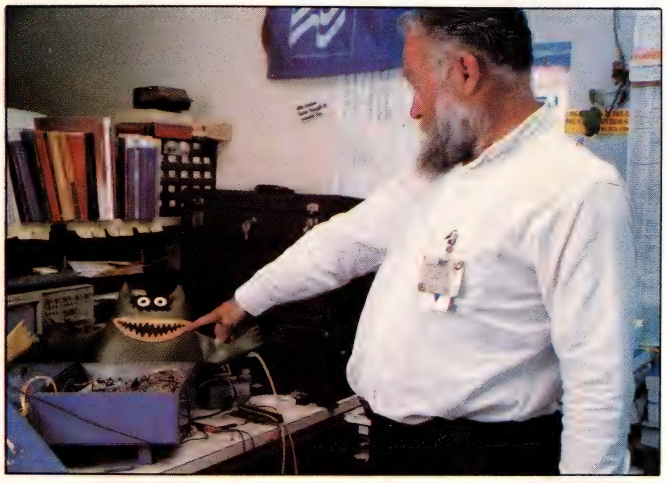
- Oscillations at very high frequencies—hundreds of megahertz—because of a single oscillating transistor
- Oscillations at dozens of megahertz arising from stray feedback around a comparator
- Oscillations at hundreds of kilohertz because of an improperly damped op-amp loop, an unhappy linear voltage-regulator IC, or inadequately bypassed power supplies
- Moderate-frequency oscillations of a switching-regulator loop because of improper loop damping
- Low-frequency oscillations coming from physical delays in electromechanical or thermal servo loops.

As these general descriptions indicate, the frequency of an oscillation is a good clue to its source. An electric-motor loop can't oscillate at 10 MHz, and a single transistor can't rattle at 100 Hz. So when an engineer complains of an oscillation, the first question I have is, "Oh, at what frequency?" Even though the frequency is often a good clue, engineers sometimes never even notice what the frequency was. This omission tends to make troubleshooting by phone a challenge.

At very high frequencies, 20 to 1000 MHz, the layout of a circuit greatly affects the possibility of oscillation. One troubleshooting technique is to slide your finger around the circuit and see if at any point an oscillation improves or worsens. Remember, knowing how to make an oscillation stronger is not worthless knowledge—that information can provide clues on how to make the oscillation weaker.

I remember being very impressed when a colleague showed me that some of the earliest IC amplifiers had a tendency to self-oscillate at 98 MHz with certain levels of output voltage. Putting a grid-dip oscillator nearby caused increases or decreases in the problem.

At very high frequencies—20 MHz to 1000 MHz—the layout of a circuit greatly affects the possibility of oscillation.



***When you find gremlins,** goblins, and bugaboos in your circuit, you have to exorcise them.*

(Heathkit makes one of these instruments whose updated name is "dip meter.") At that time I didn't have a 100-MHz scope, but I could see the rectified envelope of these high-frequency oscillations on a 25-MHz scope. So, if you see a circuit shift its dc level just because you move your finger near a transistor, you should become suspicious of high-frequency oscillations.

Of course, you will never "slide your finger around" in a circuit with high or lethal voltages.

One of the easiest ways to inadvertently cause a very-high-frequency oscillation is to run an emitter-follower transistor (even a nice, docile type such as a 2N3904) at an emitter current of 5 or 10 mA. In such a case, you can easily get an oscillation at a few hundred megahertz. So, although a good 100-MHz scope cannot spot this kind of oscillation, the resulting radiated noise can cause other circuits to go berserk and can cause an entire system to fail tests for radiated electromagnetic noise.

For such an emitter follower, a 50 or 100Ω carbon resistor directly in series with the base of the transistor (and *not* 2 or 3 in. away) can cure this tendency to oscillate. Sometimes a small ferrite bead is more suitable than a carbon resistor because it will degrade the transistor's frequency response less.

Not all problematic oscillations are high-frequency ones. An unstable switching-regulator feedback loop can oscillate at low frequencies. For troubleshooting switching-regulator feedback loops, I first recommend a network analyzer to save you troubleshooting time. A network analyzer facilitates taking data and checking out variations of the circuit in case of trouble. (However, I do tend to put more faith in real-time step response.)

Secondly, if an earlier version of your circuit has worked OK, what's the difference between the new one that does not work well and the old one that does? Be sure to keep one or more examples of the old version around so that you can make comparisons when the new circuits have troubles. (Note that I said *when*, not *if*.) Thirdly, look for components such as capacitors whose high-frequency characteristics can change if someone switched types or suppliers.

Optoisolators are another likely cause of oscillation trouble due to their wide range of dc gain and ac response. A switching-regulator IC, on the other hand, is not as likely to cause oscillations, because its response would normally be faster than the loop's frequency. But, the IC is never absolved until proven blameless. For this reason, you should have an extra module with sockets installed just for evaluating these funny little problems with differing suppliers, variant device types, and marginal ICs. You might think that the sockets' stray capacitances and inductances would do more harm than good, but in practice, you can learn more than you lose.

You can best analyze the design of a slow servo mechanism, such as that in **Fig 1,** with a strip-chart recorder because the response of the loop is so slow. (A storage scope might be OK, but a strip-chart recorder works better for me.) You might want to analyze such a servo loop with a computer simulation, such as Spice, but the thermal response from the heater to the temperature sensor is strictly a function of the mechanical and thermal mounting of those components. This relationship would rarely be amenable to computer analysis.

Comparators can misbehave

Saying that a comparator is just an op amp with all the damping capacitors left out is an oversimplification. Comparators have a *lot* of voltage gain and quite a bit of phase shift at high frequencies, hence oscillation is always a possibility. In fact, most comparator problems involve oscillation.

Slow comparators, such as the familiar LM339, are fairly well behaved. And if you design a pc-board layout so that the comparator's outputs and *all* other large, fast, noisy signals are kept away from the comparator's inputs, you can often get a good clean output without oscillation. However, even at slow speeds, an LM339 can oscillate if you impress a slowly shifting voltage

ramp on its differential inputs. Things can get even messier if the input signals' sources have a high impedance (>10 kΩ) or if the pc-board layout doesn't provide guarding.

In general, then, for *every* comparator application, you should provide a little hysteresis, or positive feedback, from the output back to the positive input. How much? Well, I like to provide about twice or three times as much as it takes to prevent oscillation near the comparator's zero-crossing frequency. This excess feedback defines a safety margin. (For more information on safety margins, see the **box,** "Pease's Principle," in the September 1, 1989, edition of EDN.) I have never seen this hysteresis technique outlined in print, so you can say you read it here first.

My suggestion for excess hysteresis is only a rule of thumb. Depending on your application, you might want to use more hysteresis. For example, a comparator in an RC oscillator may operate with 1, 2, or 10V of hysteresis, which means you can always use more than my minimum amount of excess hysteresis. Also, if you have a signal with a few millivolts of noise, the comparator that senses the signal will often want to have a hysteresis range that is three times greater than the noise.

Just the right touch

Comparators are literally very "touchy" components; that is, you can drastically alter their performance just by touching the circuit with your finger. And because

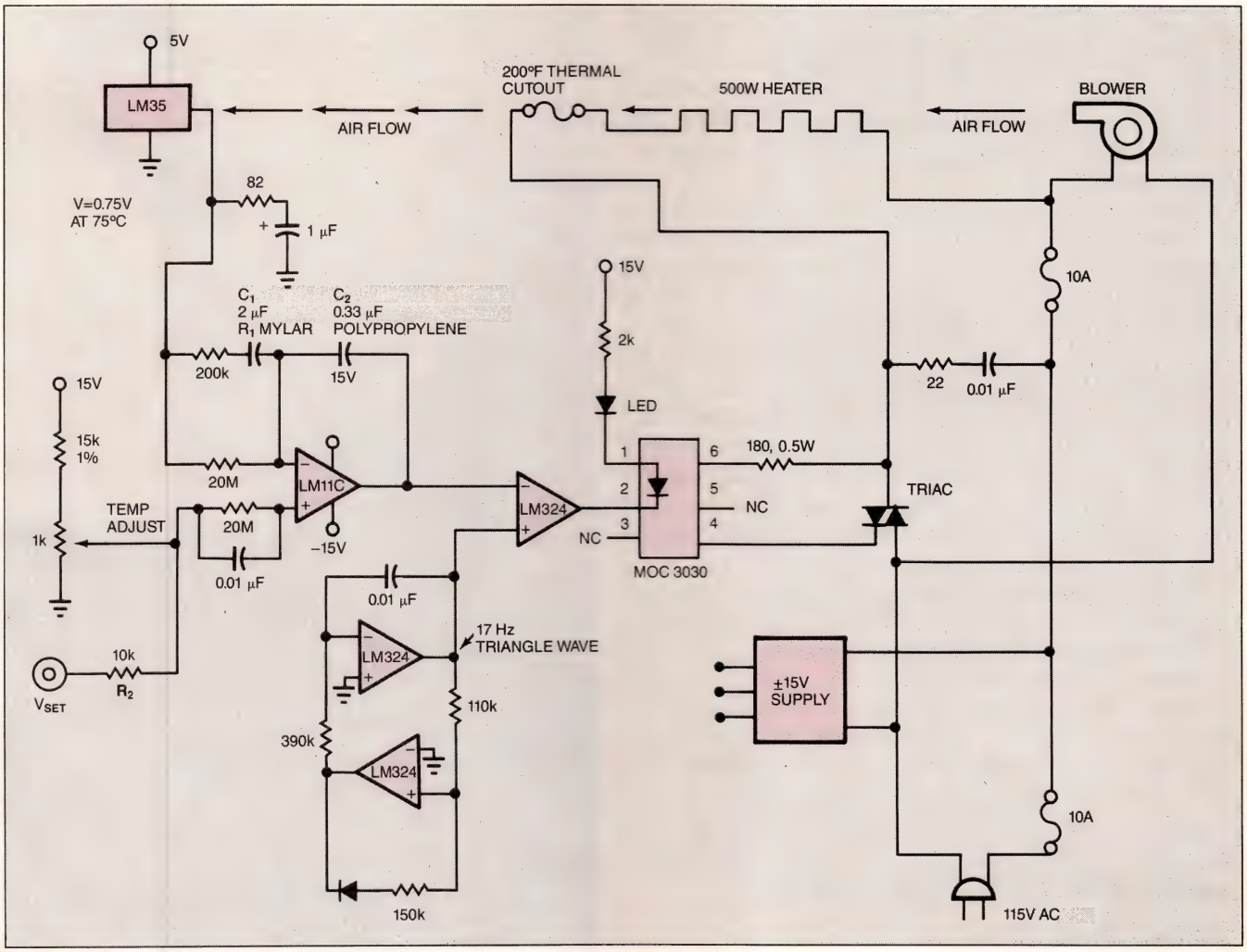


Fig 1—Stabilizing this heater's *slow servo loop and choosing the proper values for R_1, C_1, and C_2 involved applying a 1V p-p, 0.004-Hz square wave, V_{SET}, to R_2 and observing the LM11C's output with a strip-chart recorder.*

Merely stopping an oscillation is not enough; apply a tough stimulus to the circuit to see if it's safely removed from any tendency to oscillate.

comparators are so touchy, you should be prepared for the probability that your safety margin may change, for better or worse, when you go from a breadboard to a printed-circuit layout. There's no way you can predict how much hysteresis you'll need when your layout changes, so you just have to re-evaluate the system after you change it.

For faster comparators, such as the LM311, everything gets even touchier, and the layout is more critical. Yet, when several people accused the LM311 of being inherently oscillatory, I showed them that with a good layout, the LM311 is capable of amplifying any small signal, including its own input noise, without oscillating and without any requirement for positive feedback. One special precaution with the LM311 is tying the trim pins (5 and 6, normally) together to prevent ac feedback from the output (pin 7, normally), because the trim pins can act as auxiliary inputs. The LM311 data sheet in the National Semiconductor Linear Databook has carried a proper set of advice and cautions since 1980, and I recommend this advice for *all* comparators.

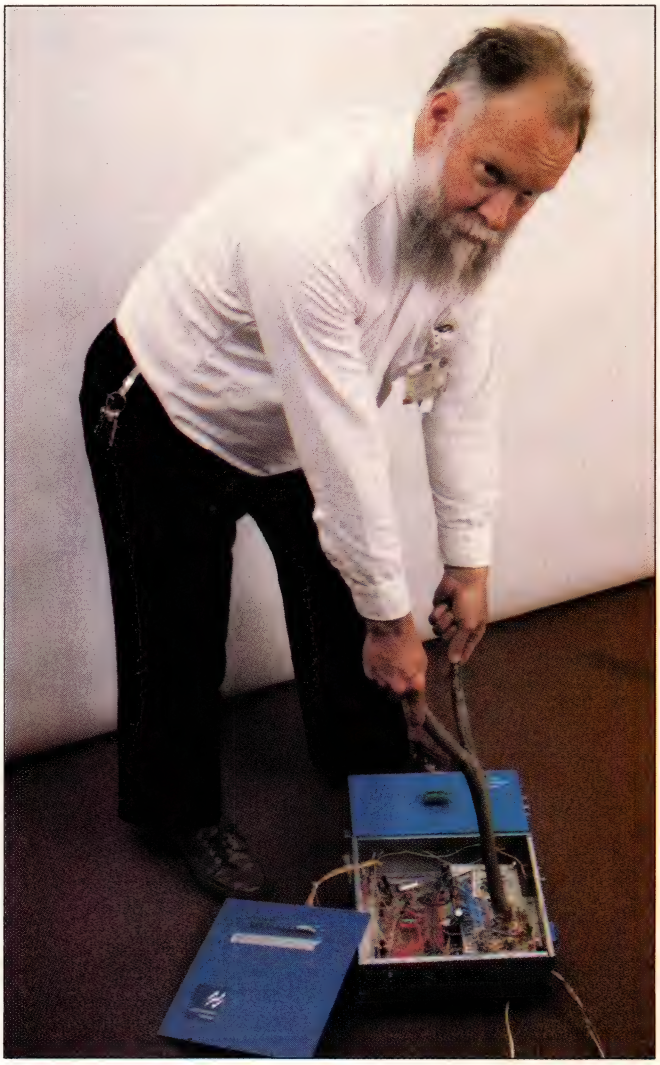
With comparators that are faster than an LM311, I find that depending on a perfect layout alone to prevent oscillation just isn't practical. For these comparators, you'll almost certainly need some hysteresis, and, if you are designing a sampled-data system, you should investigate the techniques of strobing or latching the comparator. Using these techniques results in no direct path from the output to the inputs lasting for more than just a few nanoseconds. Therefore, oscillation may be evitable. Granted, heavy supply bypassing and a properly guarded pc-board layout, with walls to shield the output from the input, may help. But you'll probably still need some hysteresis.

For some specialized applications, you can gain advantages by adding ac-coupled hysteresis in addition to or instead of the normal dc-coupled hysteresis. For example, in a zero-crossing detector, if you select the feedback capacitor properly, you can get zero effective hysteresis at the zero-crossover point while retaining some hysteresis at other points on the waveform. The trick is to let the capacitor's voltage decay to zero during one half-cycle of the waveform. But make sure that your comparator with ac-coupled hysteresis doesn't oscillate if the incoming signal stops.

Comparators *do* have noise

Data sheets don't talk about the noise of comparators, but comparators *do* have noise. Depending on which unit you use, you may find that each comparator has an individual "noise band." When a differential input signal enters this band slowly from either side, the output can get very noisy rail to rail, which results in amplified noise or oscillation. The oscillation can continue even if the input voltage goes back outside the range where the circuit started oscillating. Consequently, you can easily set up your own test in which your figure for offset voltage, V_{OS}, doesn't agree with the manufacturer's measured or guaranteed values. Indeed, it can be tricky to design a test that *does* agree.

For my tests of comparator V_{OS}, I usually set up a classic op-amp oscillator into which I build a specific amount of hysteresis and a definite amount of capaci-



Photographs by Peggi Willis

It takes a lot of skill *and the right instrument to divine the source of perplexing problems.*

tance, so that the unit will oscillate at a moderate, controlled frequency. If you're curious, write to me for the details, which are not trivial.

Another way to avoid V_{OS} trouble with comparators is to use a monolithic dual transistor as a differential-amplifier preamplifier stage ahead of the comparator. This preamp can add gain and precision while decreasing the stray feedback from the output to the input signal.

Common-mode excursions unpredictable

After curing oscillation, most complaints about comparators are related to their common-mode range. We at National Semiconductor's applications engineering department get many calls from engineers who want to violate comparators' common-mode specs, but they're not always happy with our answers. I guess the complaints are partly the fault of the manufacturers for not being clear enough in their data sheets.

By way of contrast, most engineers know well that an op amp's common-mode-voltage range, V_{CM}, is defined provided that both inputs are at the same level. This spec makes sense for an op amp because most operate with their inputs at the same level. But in most cases, a comparator's inputs are not at the same level. As long as you keep both inputs within the comparator's specified common-mode range, the comparator's output will be correct.

But, if one input is within the common-mode range and the other is outside that range, one of three things could happen, depending on the voltages and the particular comparator involved. For some input ranges you can overdrive the inputs and still get perfectly valid response; for other input ranges, you can get screwy response but cause no harm to the comparator; and for others, you'll instantly destroy the comparator.

For example, for an LM339-type comparator running on a 5V supply, if one of its inputs is in the 0-to-3.5V range, then the other input can range from 0 to 36V without causing any false outputs or causing any harm to the comparator. In fact, at room temperature, the out-of-range input can go to -0.1V and still produce the correct output.

But, heaven help you if you pull one of the inputs below the -0.1V level, say to -0.5 or -0.6V. In this case, if you limit the comparator's input current to less than 5 or 10 mA, you won't damage the comparator. But even if no damage occurs, the outputs of any or all of the comparators in the IC package could respond falsely. Current can flow almost anywhere within the IC's circuitry when the substrate diode, which is inherent in the device's input transistor, is forward biased. It is this current that causes these false outputs.

***When oscillations get nasty**, you need a scope with pinpoint triggering to help you study the problem.*

We'll try to be more clear about V_{CM} specs in the future. Maybe next time at National Semiconductor, we'll phrase the spec sheet's cautions a little more vigorously. Still, if you stay within their rated common-mode range, comparators are not that hard to put to work.

Of course, some people disdain reading data sheets, so they get unhappy when we tell them that differential signals larger than ± 5V damage some fast comparators. But, this possibility has existed since the existence of the μA710, so you'll have to clamp, clip, or attenuate the input signal—differential or otherwise.

An unmentionable problem

Something else that does *not* usually get mentioned in a data sheet are common-mode slew problems. The LM311 is one troublemaker, but to some extent all comparators can have these troubles. If one input suddenly slews up to exceed the other's level, you may see an unexpected, extra delay before the comparator's output changes state. This delay arises because the comparator's nodes do not slew fast enough internally for its outputs to respond. For example, a 10V step can accrue an extra 100-nsec delay compared with the the delay for a 100-mV step. And if both inputs slew together, the output can spew out indeterminate glitches or false pulses even if the differential inputs don't cross over. Be careful if your circuit cannot tolerate such glitches.

Come to think of it, I get occasional complaints from

You should have an extra module with sockets just for evaluating funny little problems due to differing suppliers, variant device types, or marginal ICs.

engineers along the lines of, "I've been using this comparator for years without any trouble, but suddenly it doesn't work right. How come?" When we inquire, we find that the comparators have been operating very close to the edge of the "typical" common-mode range, well beyond any guaranteed values. Although these engineers have been getting away with crowding the limits for years, the latest batch of comparators gives them trouble. Some of our best friends depend on us to have our parts meet those *typical* specs, and it's always painful for us to tell them that they really ought to depend only on *guaranteed* specs.

If you need three op amps and one comparator, can you use a single LM324? Well, op amps are not necessarily bad as comparators, but they sure are slow, and the LM324 is among the slowest. Not only is its slew-rate slow, but if you put in an overdrive of just 5 mV more than V_{OS}, the output will respond at only 0.01V/μsec—not even as fast as its specified slew rate. An LF351 or one fourth of an LF347 will respond somewhat faster. So if you want to use an op amp as a comparator, you'd better need merely a slow comparator. (Note, however, that one LM358 plus one LM392 will give you effectively three fourths of an LM324 plus one fourth of an LM339, and the space taken by the two 8-pin miniDIPs would be only 4% more than that taken by a single 14-pin DIP.)

But, even so, some people *do* use op amps as slow, precision comparators. Even though op amps are generally not characterized as comparators, you can engineer such a circuit successfully. For example, the LM709 minus its compensation capacitors is a surprisingly competent, fairly quick comparator. But, please don't overdrive and damage the inputs.

Conversely, I am occasionally asked, "Can I put some damping capacitors on an LM339 and use it as a unity-gain follower?" The general answer is NO! because the LM339's phase lags are too squirrelly to be controlled by any possible compensation scheme. But I have used the slower LP339 and LP365 successfully this way, as a slow inverter or slow follower.

Even buffered circuits can oscillate

Any circuit that adds current gain can oscillate—even a buffer. Let's agree that a buffer is some kind of linear amplifier that has a lot of current gain. Some have a voltage gain around 0.90 or 0.95. Others have gains as high as 10 or 20 because their outputs must swing 50 or 100V p-p—or more. Even emitter followers, which you'd expect to be very docile because their voltage gain is less than 1, have a tendency to "scream" or oscillate at high frequencies. So whether you buy a buffer or "roll your own," watch out for this problem.

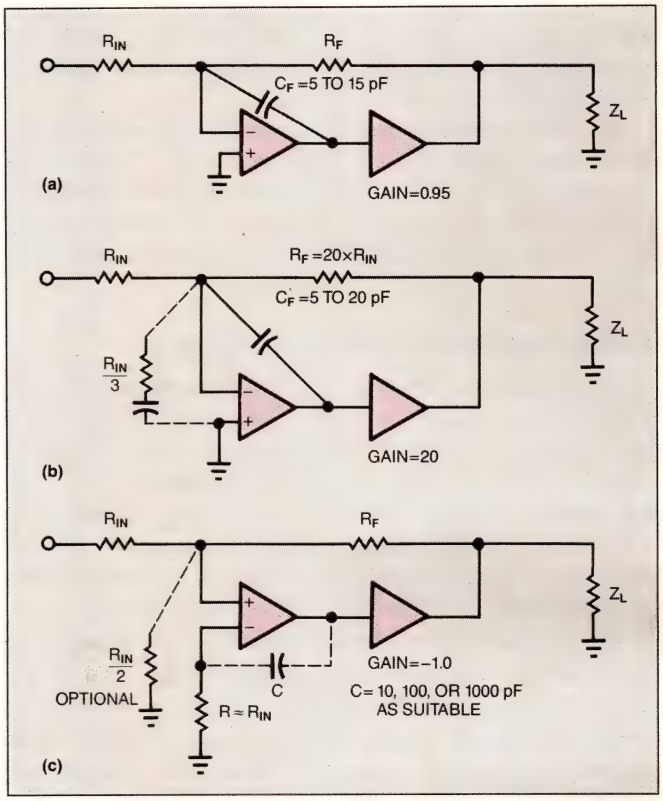


Fig 2—Depending on the gain of the buffer, *you can use these three schemes to stabilize a buffered amplifier.*

Also, a buffer can have a high-frequency roll-off whose slope increases suddenly at 40 or 60 MHz and thus can contribute phase shift to your loop back down at 6 or 10 MHz. You can beat this problem, but you have to plan. A buffer can also add a little distortion, which the op amp cannot easily cancel out at moderate or high frequencies. Since buffers don't usually have a spec on this distortion, beware. Also, if you're running the output's quiescent bias current as Class AB, you must be sure that the dc operating current is stable and not excessive. You must set it high enough so that you don't get distortion but not so high that power consumption becomes excessive.

One of my standard procedures for stabilizing a unity-gain follower stage is to put feedback capacitance around just part of the loop (**Fig 2a**). This circuit tolerates capacitive loads, because the buffer decouples the load while the feedback capacitor around the op amp provides local stability. Most unity-gain buffers,

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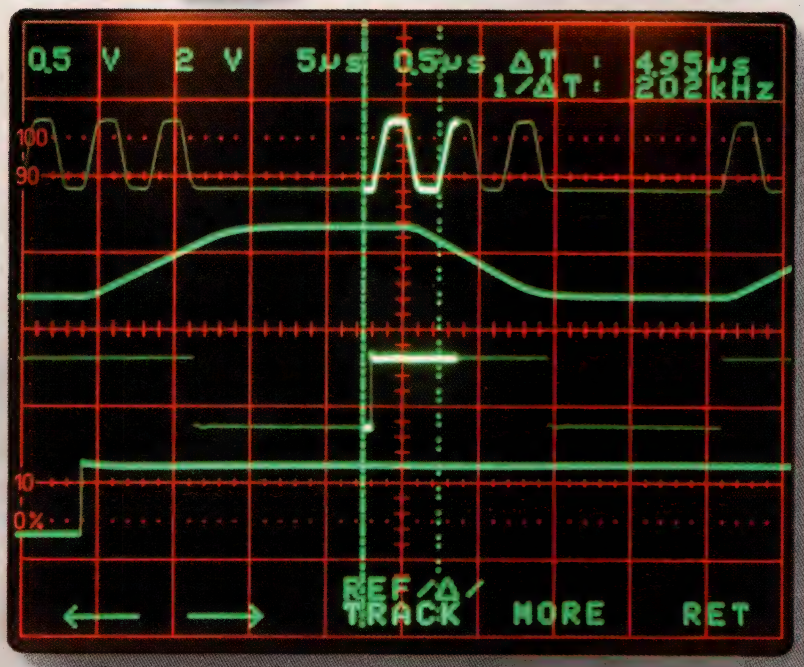

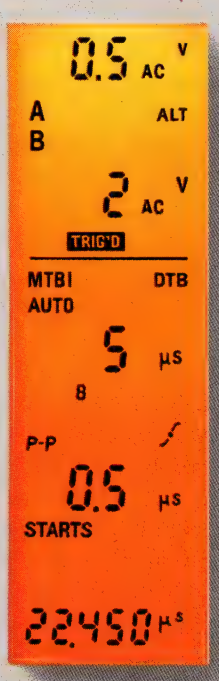

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Comparators deserve the same degree of respect and amount of fair treatment as fast op amps do.

whether monolithic, hybrid, or discrete, are unstable with inductive sources, so keep the input leads short. A series resistor may help stability, as it does for the LM310, but it will slow down the device's response.

Many high-speed buffers have the chore of driving loads in the range of 50 to 150Ω. Driving these loads can require a lot of current, which leads to overheating. Plan your heat sinks carefully to keep the device from exceeding its rated maximum temperature. Most buffers don't have any thermal shutdown feature, but the new LM6321s and LM6325s show that an op amp, at least, can have such features designed in. When using buffers to drive remote loads, be sure that the transmission lines or cables have suitable termination resistances on both ends to prevent reflections and ringing. If you can afford the voltage drop, it's best to put about 50Ω between the buffer and its cable.

When your buffer provides a lot of extra voltage gain, you must make sure that the gain rolls off in a well-engineered way at high frequencies, or the loop will be unstable. If the buffer-amplifier has a positive gain, as in **Fig 2b,** you can use capacitive feedback around the main amplifier. But when the buffer-amplifier has a gain of −10 (**Fig 2c**), you may want to apply a feedback capacitor from the output of the buffer-amplifier to the noninverting input of the op amp. In some cases, you can achieve stability by putting a series RC damper from the noninverting input to ground to increase the noise gain, but this trick doesn't always work. Damping this loop is not easy.

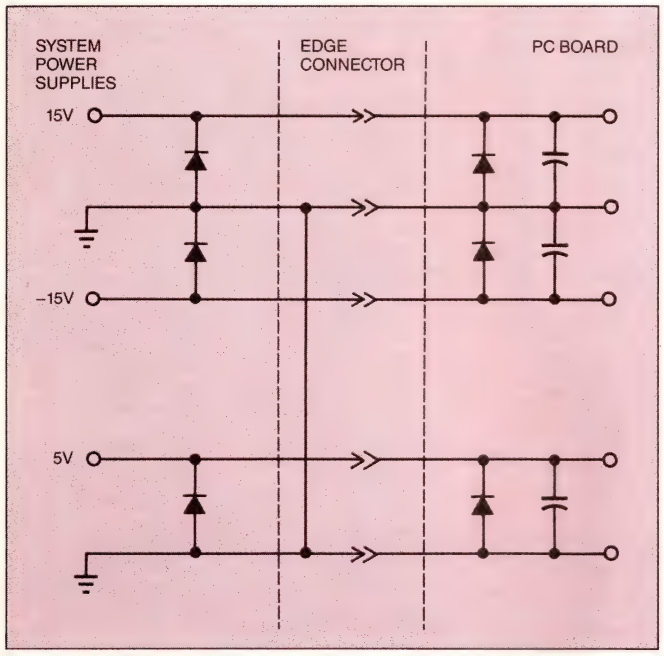

Fig 3—Installing antireversal diodes *in the system power supplies and on each pc board greatly reduces the chance of damaging the supplies or the circuitry with inadvertent short circuits or polarity reversals.*

A circuit that inadvertently latches up presents a problem exactly opposite that of an oscillating circuit. Or, you could correctly say that a latched-up circuit is an oscillator with zero frequency. Although latched-up circuits demand troubleshooting, the good thing about them is that they sit right there and let you walk up to them and touch them. And you can measure everything with a voltmeter to find out how they became latched. This state of affairs doesn't mean that troubleshooting them is easy, because sometimes you can't tell how the latched-up circuit got into its present state. And in an integrated circuit, there can be paths of carriers through the substrate that you can't "put your finger on."

The worst aspect of latched-up circuits is that some are destructive, so you can't just sit there and let them remain latched up forever. Two approaches for attacking destructive latches are:

- Turn off the power quickly, so the latched-up circuit cannot destroy anything. Try turning on power for short pulses and watching the circuit as it *approaches* the destructive latch condition.
- Use an adjustable current-limited supply with a zero or small output capacitance, so when the circuit starts to latch, the fault condition can easily pull the current-limited power supply's voltage down.

Another way to inadvertently generate a latched-up condition is to turn on the outputs of your multiple-output power supply in the "wrong" sequence. Some amplifiers and circuits get quite unhappy when one supply (usually the positive one) turns on first. Automatic power-supply sequencers can help you avoid this problem. An antireversal rectifier across each supply can help, too, and is always a good idea for preventing damage from inadvertently crossed-up power-supply leads or supply short circuits.

I used to get calls every few months from people who asked me if it was okay to ship products that contained LM108s that may have had +15V on their −15V pins and vice versa. Telling them, "Don't ship it—junk it. And, next time put antireversal diodes on each supply," was always painful for me. Specifically, you should add these antireversal rectifiers across each bus in your system to protect the loads and circuits. Also add an antireversal rectifier across each power

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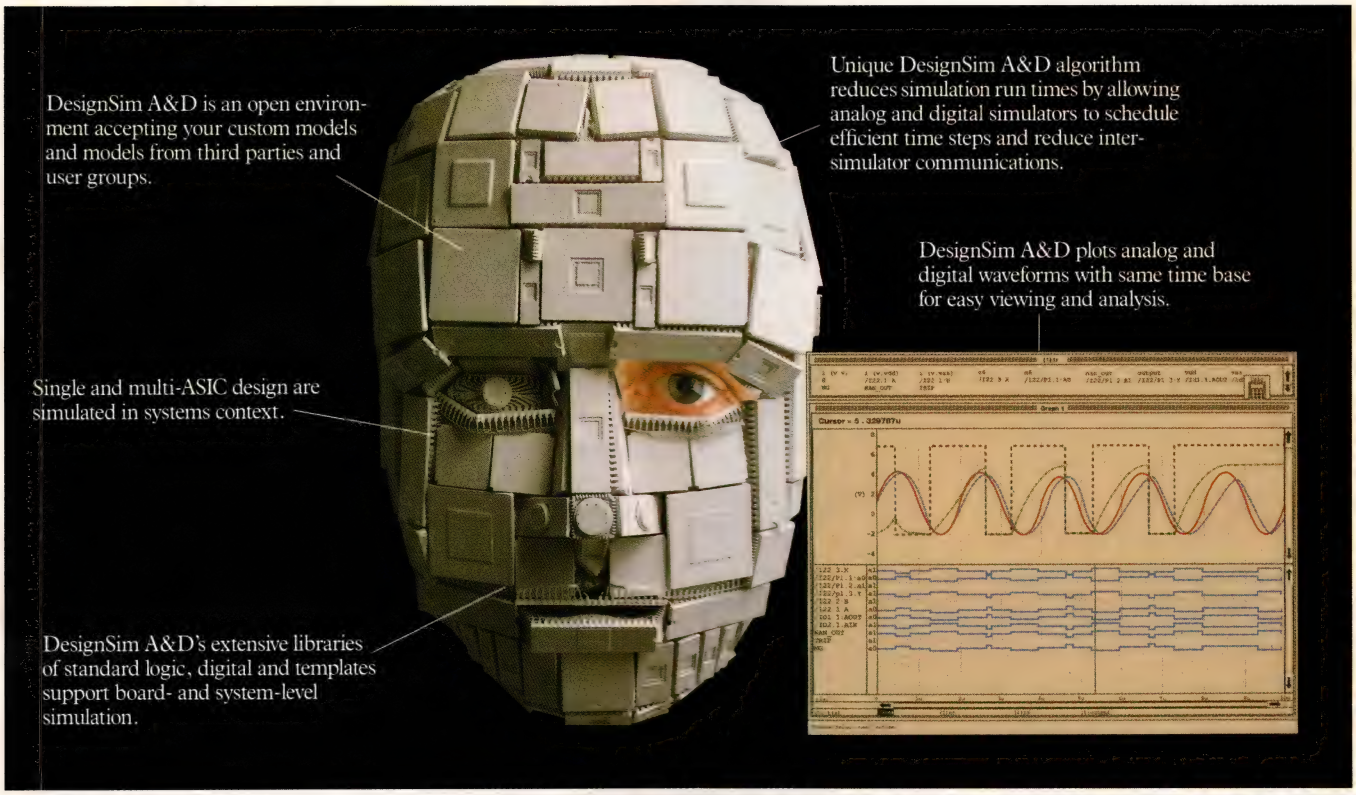

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supply to protect the supplies (**Fig 3**). Some people think that leaving parts out is a good way to improve a circuit's reliability, but I've found that putting in the right parts works best.

If you have any doubt that your fixes are working, try heating or cooling the suspected semiconductor device. Don't bother heating passive components such as resistors, capacitors, and inductors because their characteristics don't change enough with temperature to matter. Even if a circuit doesn't get better when heated, it can get worse when cooled, so also take a peek at the circuit while applying some freeze mist.

My point is that merely stopping an oscillation is not enough. You must apply a tough stimulus to the circuit and see whether your circuit is close to oscillation or safely removed from any tendency to oscillate. This stricture applies not only to regulators but also to all other devices that need oscillation-curing procedures.

For example, if a 47Ω resistor in the base of a transistor cures an oscillation, but 24Ω doesn't, and 33Ω doesn't, and 39Ω still doesn't, then 47Ω is a lot more marginal than it seems. Maybe a 75Ω resistor would be a better idea—just so long as 100 or 120 or 150Ω resistors are still safe.

In other words, even though wild guesses and dumb luck can sometimes cure an oscillation, you cannot cure oscillations safely and surely without some thoughtful procedures. Furthermore, somebody who has an appreciation for the "old art" will have the best results.

I certainly do not want to say that technicians can't troubleshoot oscillations simply because they don't know the theory of why circuits oscillate—that's not my point at all. I will only argue that a green or insensitive person, whether a technician or an engineer, can fail to appreciate when a circuit is getting much too close to the edge of its safety margins for comfort. Conversely, everyone knows the tale of the old-time unschooled technician who saves the project by spotting a clue that leads to a solution when all the brightest engineers can't guess what the problem is. EDN

Author's biography

For more information about Bob Pease, see the ***box,*** *"Who is Bob Pease, anyway?" on page 148 of the January 5, 1989, edition of EDN.*

Article Interest Quotient (Circle One)
High 479 Medium 480 Low 481

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Spice model handles linear optocouplers

Steven C Hageman
Calex Mfg Co, Pleasant Hill, CA

The Spice model for linear optocouplers in **Listing 1** yields results that correlate closely with both measured results and data-sheet specifications. The calculated large-signal rise and fall times correlate exactly with the measured values; and, at a given operating point, the model yields excellent dc results. Only the transient response at low forward currents shows aberrations.

To derive the model's parameters, you must have a good data sheet for your optocoupler. You must also know the approximate operating point of the optocoupler's diode and transistor in your circuit **(Fig 1)**.

To model the diode given the operating-point information I_D and V_D, use the following values for the parameters required by Spice's D model statement **(Listing 1)**:

- IS—Calculate the value of the series current from the classical diode equation using the diode's forward voltage drop.
- RS—A reasonable average value for optoisolators' series resistance is 4Ω. (The more-exact value in the **listing** was obtained elsewhere.)
- EG—The energy gap of GaAs semiconductors is 1.43.
- BV—The data sheet's reverse breakdown voltage.
- IBV—The specified reverse current at the reverse breakdown voltage, BV.
- CJO—The zero-bias diode capacitance from the data sheet.
- TT—The transit time for the typical emitter is 4 nsec. This spec is critical only for the input circuit's response; the phototransistor swamps the output response.

One peculiarity of Spice is that it requires you to insert a zero-voltage voltage source in a circuit, so that you can sense current. VSENSE senses the diode's current; FC is the dependent source in the transistor's circuit (F designates a current-controlled current source). The Spice program statement, "FC 3 4 VSENSE 1.0M," links FC to VSENSE, where the 1.0M term is the controlled source's current gain—the ratio of the optoisolator's current-transfer ratio (CTR) to its β. In this case, the device's spec sheet lists its CTR as 55 and its β as 550. The M in the 1.0M parameter means "milli." (Spice is case insensitive; to indicate mega, you must enter "MEG.")

The CTR of optoisolators varies by about 2:1 per decade of forward current, but this variation affects only the dc bias-point accuracy. If you need more CTR accuracy, you could construct a Spice polynomial source for FC. Note that the transistor's parasitic capacitances, CCE, CCB, and CBE, are also fixed in this model. These fixed capacitances result in very little loss of ac and transient accuracy.

You model the rest of the phototransistor in a similar fashion to that of the input diode. Given your circuit's

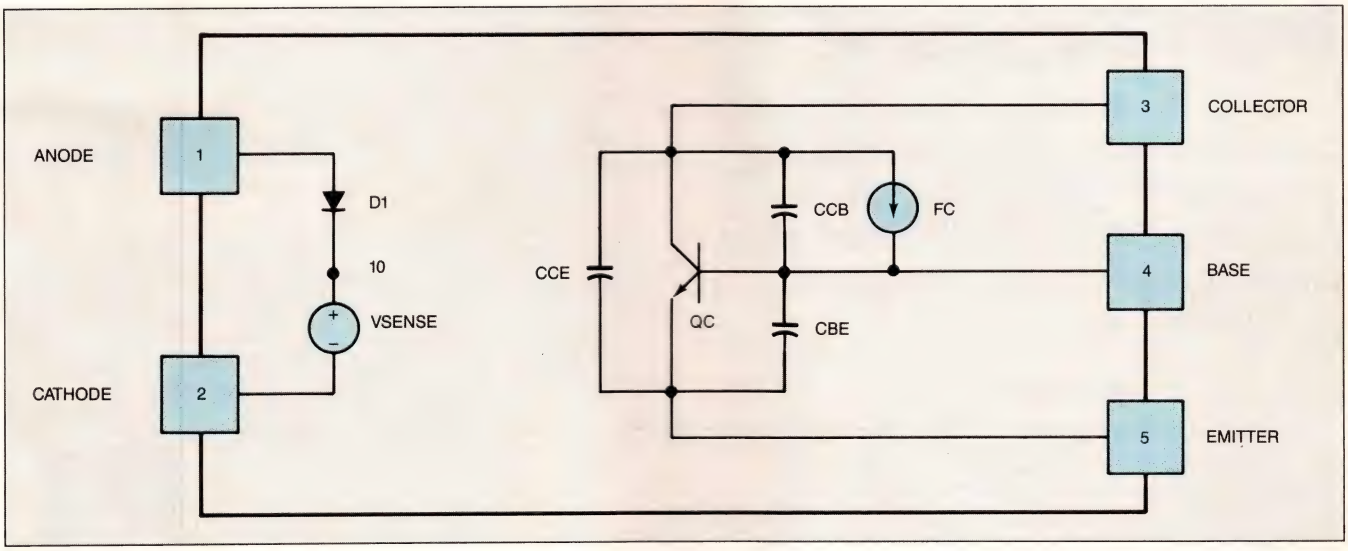
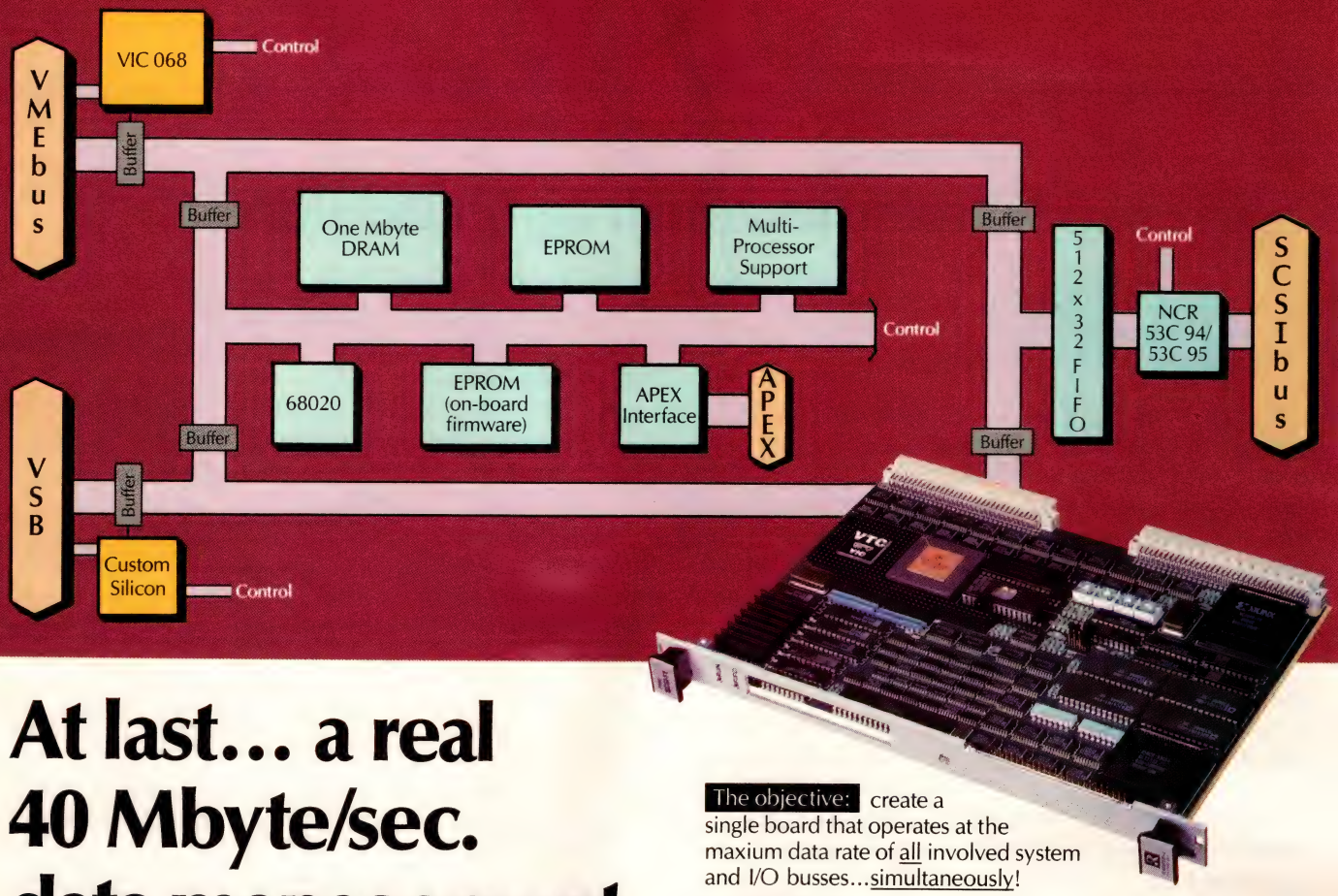


Fig 1—This Spice optoisolator model, *though somewhat simplified, gives good results. The voltage source in the diode's circuit is a quirk that Spice requires to drive the dependent current source, FC, which models the phototransistor's optical base drive.*



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approximate operating point (I_C, V_{CE}, V_{BE}, and V_{CB}), you obtain the phototransistor's capacitance and β from its data sheet and insert these values in the program's capacitor statements and Q (transistor) model. If your actual circuit doesn't use the base node, simply connect a dummy 1-GΩ resistor from the base to emitter nodes.

EDN

To Vote For This Design, Circle No 748

LISTING 1—SPICE OPTOISOLATOR MODEL

```
**************************************************************
* CNY17-1 SUBCIRCUIT MODEL - BY: S.C. HAGEMAN
*
* USAGE: XNAME A K  C B E  CNY17-1
*               ---+ -----+
*                  ¦      ¦
*                  ¦      +-- PHOTOTRANSISTOR
*                  ¦
*                  +-- GaAs EMITTER
*
**************************************************************
.SUBCKT CNY17-1   1 2  3 4 5
*
* PHOTO EMITTER
*
D1 1 10 DCNY17
VSENSE 10 2 DC 0.0
*
* PHOTO TRANSISTOR
*
* FC GAIN = CTR/BETA
*
FC 3 4   VSENSE  1.0M
QC 3 4 5 QCNY17
*
* THE CAPACITANCES ARE SPECIFIED FOR VCE = 2V IC = 2MA
*
CCB 3 4 8.5P
CBE 4 5 11P
CCE 3 5 6.8P
*
* PHOTOEMITTER MODEL
*
.MODEL DCNY17  D (IS=7.161E-21 RS=3.938 EG=1.430 BV=6
+                 IBV=100.0E-6 CJO=40.00E-12 TT=5.000E-9)
*
* PHOTOTRANSISTOR MODEL
*
.MODEL QCNY17 NPN (BF=550)
*
.ENDS  CNY17-1
**************************************************************
```

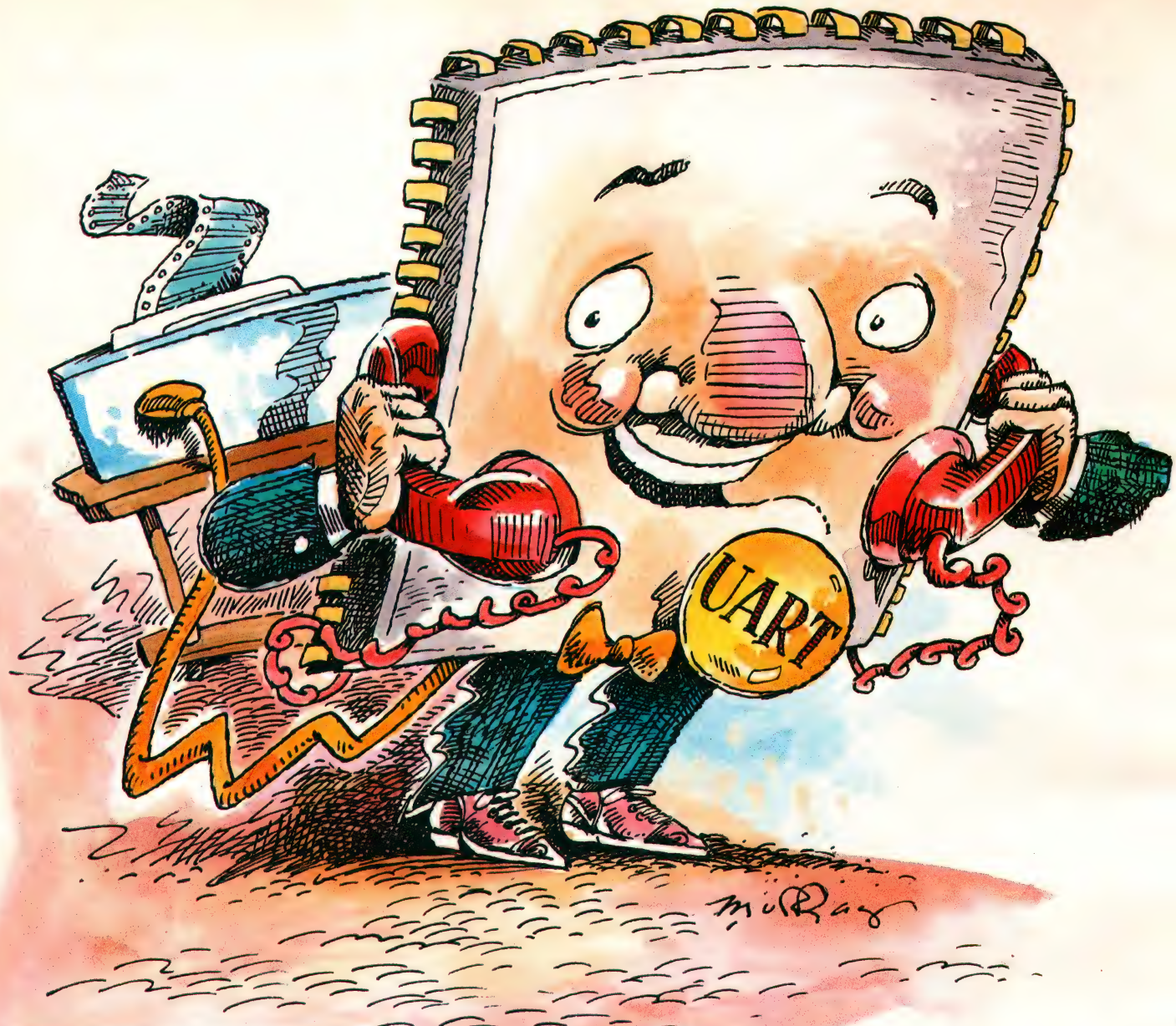
Algorithm speeds trigonometric math

Robert Zigon
International Laser Machines, Indianapolis, IN

The following algorithm suits fixed-point, binary arithmetic much better than conventional power-series evaluations of sine and cosine functions. The algorithm makes use of the simple trigonometric identities:

$$\sin\theta = \tan\theta/\sqrt{1 + \tan^2\theta} \text{ and } \cos\theta = 1/\sqrt{1 + \tan^2\theta}.$$

Assume that you have a vector, (X,Y), that you wish to rotate through some arbitrary angle, θ, as



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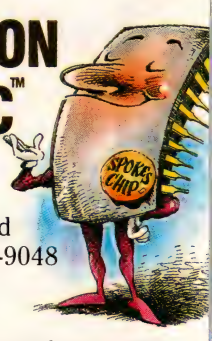

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quickly as possible to generate a new vector (X′, Y′):

$$\begin{bmatrix} X' \\ Y' \end{bmatrix} = \begin{bmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{bmatrix} \begin{bmatrix} X \\ Y \end{bmatrix},$$

which is equivalent to

$$X' = X\cos\theta + Y\sin\theta$$
$$Y' = -X\sin\theta + Y\cos\theta.$$

To understand how this algorithm suits binary arithmetic, first choose a fixed-point value for θ: $\theta_k = \arctan 2^{-k}$. If you substitute θ_k for θ in the previous identities, you get

$$\sin\theta_k = \tan(\arctan 2^{-k})/\sqrt{1 + \tan^2(\arctan 2^{-k})} \text{ and}$$
$$\cos\theta_k = 1/\sqrt{1 + \tan^2(\arctan 2^{-k})}.$$

Simplifying:

$$\sin\theta_k = 2^{-k}/\sqrt{1 + (2^{-k})^2}$$
$$\cos\theta_k = 1/\sqrt{1 + (2^{-k})^2}.$$

Computers can handle these last two expressions easily by doing the exponentiation with shifts and using common algorithms for extracting square roots.

To apply this method to the vector-transformation problem, substitute the above equations in the first equations to yield

$$X' = (1/\sqrt{1 + 2^{-2k}}) \times (X + 2^{-k}Y)$$
$$Y' = (1/\sqrt{1 + 2^{-2k}}) \times (Y - 2^{-k}X).$$

You can precompute the quotient terms for the above equations and load them into a table. Thus, your program will not have to waste time extracting roots and dividing. The product of X or Y and 2^{-k} only involves a right shift by k bits.

TABLE 1—ANGLE INCREMENTS

k	2^{-k}	$\theta_k = \text{ARCTAN } 2^{-k}$
0	1	45.0°
1	½	26.565°
2	¼	14.036°
3	⅛	7.125°
4	1/16	3.576°
5	1/32	1.789°
6	1/64	0.895°
•	•	•
•	•	•
•	•	•
n	$(½)^n$	$\text{ARCTAN}^{-1}(½^n)$

However, this method hasn't really solved the translation problem. The equations, as constituted, will not rotate a vector through any *arbitrary* angle θ; the equations restrict θ to θ_k, which can assume only the values in **Table 1.**

To use the equations for any arbitrary angle, you must sum various values of θ_k using

$$\theta = \sum_{k=0}^{\infty} \alpha_k\theta_k, \ \alpha_k = 0 \text{ or } 1.$$

The value for α depends on whether or not you need a particular angle increment, θ_k, to contribute to the arbitrary rotation angle, θ. EDN

To Vote For This Design, Circle No 749

Walsh functions power FSK transmitter

Tom Dahlin
3M Corp, St Paul, MN

A Walsh-function generator powers the 600/1200-Hz FSK (frequency-shift keying) transmitter in **Fig 1.** Walsh functions are a digital analog of Fourier series. Walsh functions combine orthogonal digital waveforms, rather than orthogonal sinusoidal waveforms, to generate arbitrary analog waveforms.

The circuit shown accepts a serial-data stream and generates the corresponding FSK sinusoidal waveforms. The circuit has its own timebase and supplies a 1200-Hz master clock for the communications controller, which furnishes the serial data.

In the circuit, IC_1, an MC1441 baud-rate generator, divides the 1.8-MHz reference to provide five synchronous clocks ranging from 19,200 to 1200 Hz for the Walsh-function generator. The serial-data stream tog-

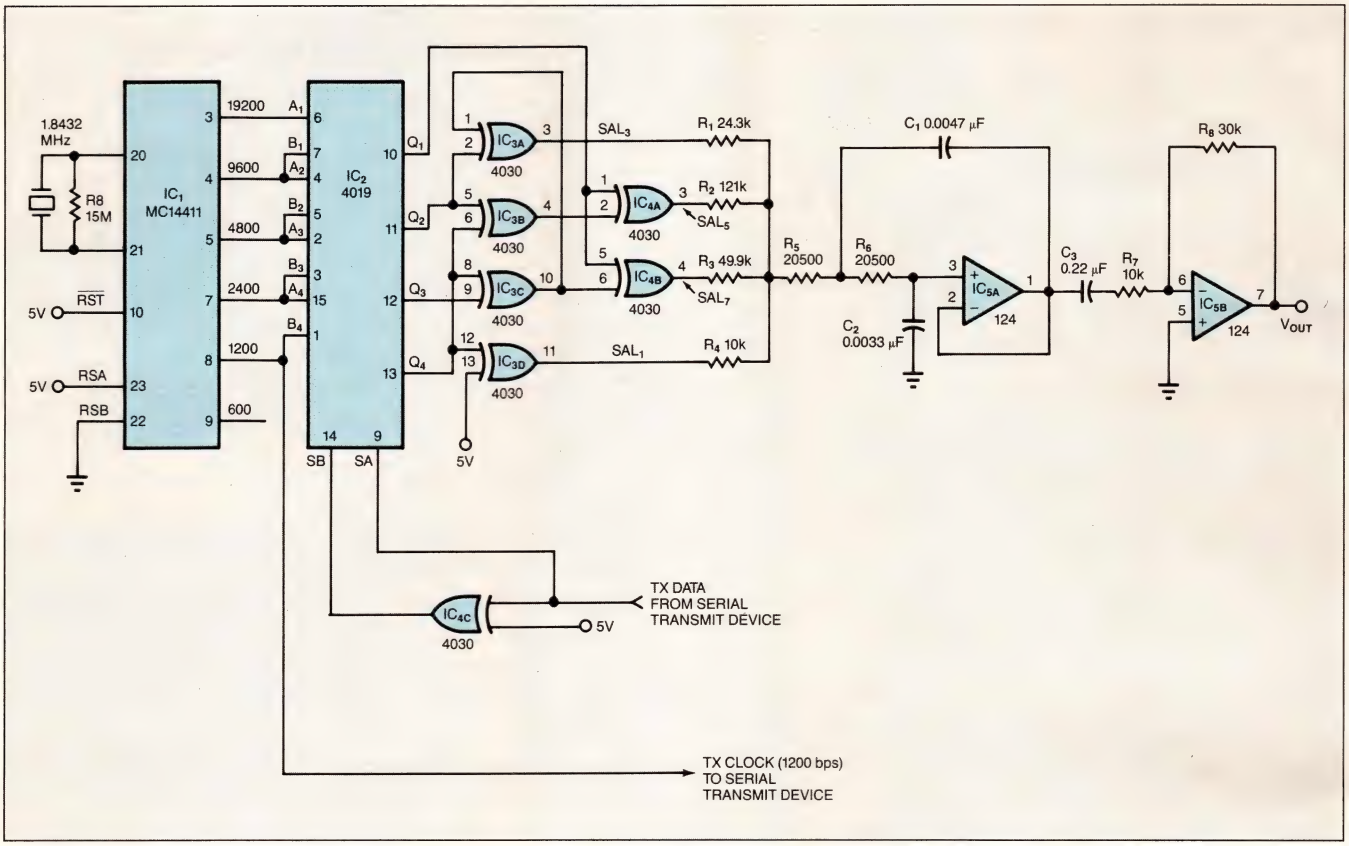

Fig 1—The XOR gates in this circuit *generate Walsh functions that combine to form FSK signals.*

gles the quad dpst switch, IC_2. The switch selects four of the five clocks and gates either the 19,200-through 2400-Hz clocks or the 9600- through 1200-Hz clocks to the Walsh-function generator. The first group of four clocks generates the 1200-Hz FSK tone; the second group generates the 600-Hz FSK tone.

The Walsh-function generator comprises the six exclusive-OR gates, IC_3 and IC_4. As the timing diagram in **Fig 2** shows, the four clock outputs of IC_2—Q_1, Q_2, Q_3, and Q_4—drive the XOR gates to generate the Walsh functions: SAL_1, SAL_3, SAL_5, and SAL_7. Weighting resistors R_1, R_2, R_3, and R_4 sum these signals to form the composite output signal.

The first section of the LM124 dual op amp, IC_5, is a lowpass, Bessel filter with a 1500-Hz, −3-dB point. The second section sets the circuit's output level.

EDN

References

1. Jacoby, B, "Walsh Functions: A Digital Fourier Series," *Byte*, September 1977.

2. Harmuth, H F, "Applications of Walsh Functions in Communications," *IEEE Spectrum*, November 1969.

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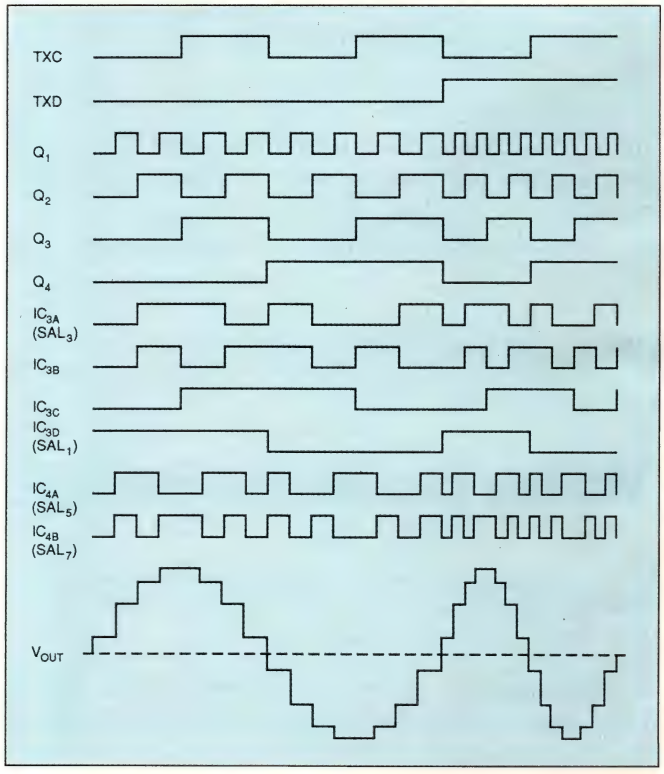

Fig 2—Walsh series are orthogonal *digital signals that combine to form arbitrary waveforms, much as Fourier series combine orthogonal sinusoids.*

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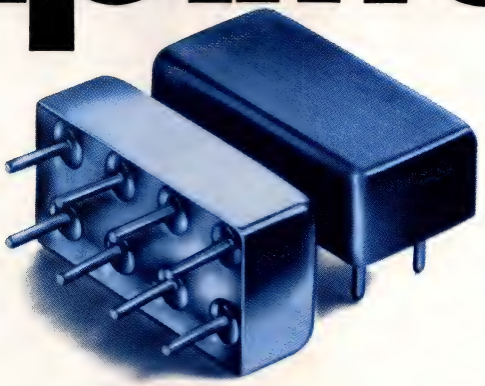

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CIRCLE NO 102

C118 REV. E

Design Entry Blank

$100 Cash Award for all entries selected by editors. An additional $100 Cash Award for the winning design of each issue, determined by vote of readers. Additional $1500 Cash Award for annual Grand Prize Design, selected among biweekly winners by vote of editors.

To: Design Ideas Editor, EDN Magazine
Cahners Publishing Co
275 Washington St, Newton, MA 02158

I hereby submit |my| Design Ideas entry.

Name _____

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(Must accompany all Design Ideas submitted by US authors)

Entry blank must accompany all entries. Design entered must be submitted exclusively to EDN, must not be patented, and must have no patent pending. Design must be original with author(s), must not have been previously published (limited-distribution house organs excepted), and must have been constructed and tested.

Exclusive publishing rights remain with Cahners Publishing Co unless entry is returned to author or editor gives written permission for publication elsewhere.

In submitting my entry, I agree to abide by the rules of the Design Ideas Program.

Signed _____

Date _____

ISSUE WINNER

The winning Design Idea for the May 25, 1989, issue is entitled "Circuit transforms PC into data analyzer," submitted by Allan W Overcast of Montana State University (Bozeman, MT).

Your vote determines this issue's winner. All designs published win $100 cash. All issue winners receive an additional $100 and become eligible for the annual $1500 Grand Prize. **Vote now,** by circling the appropriate number on the reader inquiry card.

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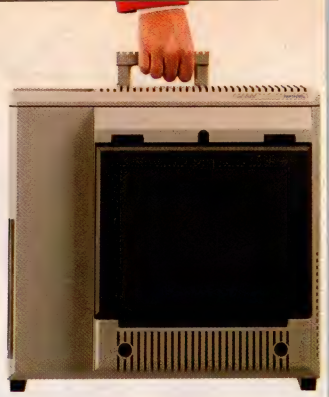
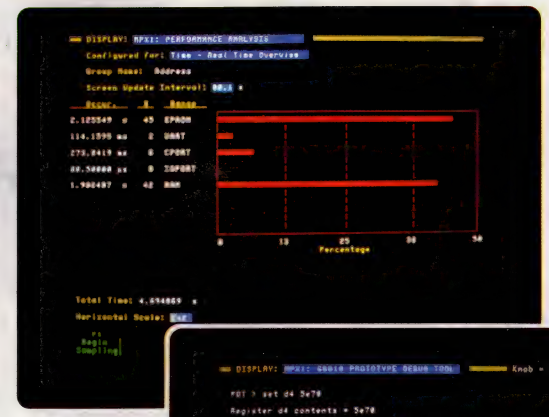
CIRCLE NO 104

TEK'S NEW PRISM 3000 FAMILY BREAKS THE LOGIC ANALYSIS BARRIER.



The new Prism 3000 Series is nothing less than a breakthrough in the evolution of logic analysis: once you see what it can do, you may scarcely imagine doing without it.

Now digital designers and integrators can start with all the speed, channels and memory depth they need — without tradeoffs. They can mix-and-match tools for their specific needs, including 8, 16 and 32-bit microprocessor debug modules brimming with features never before possible in a logic analyzer. They can add other modules, such as for high-speed timing and waveform analysis, later.



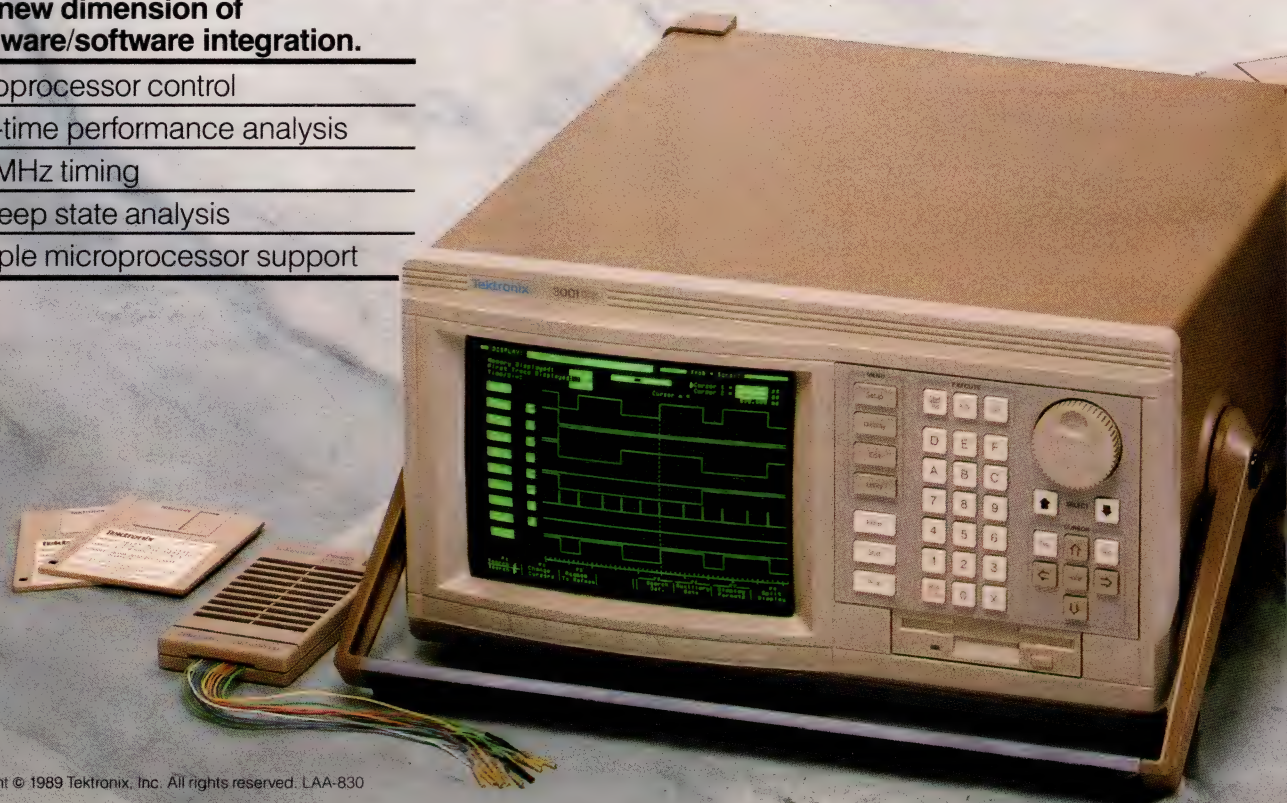
You can view 200 MHz timing and 8K of state data per channel, all time-correlated and integrated on the same display.

Observe data from multiple microprocessors or time-bases simultaneously. Set up

(Above, left) Real-time performance analysis as displayed on the Prism color monitor. (Left) The Prototype Debug Tool provides easy access to microprocessor control and debug functions, including the ability to set hardware and software breakpoints, and to patch registers and memory.

The new dimension of hardware/software integration.

- Microprocessor control
- Real-time performance analysis
- 200 MHz timing
- 8K deep state analysis
- Multiple microprocessor support



The Prism 3002P configuration features a slide-away keyboard and a 640x400 flat panel display that folds against the mainframe when not in use.

state and timing sections to cross-trigger, synchronize and arm each other, so you know exactly when and in what time relationship events occur.

Push beyond microprocessor observation into emulator-like microprocessor *control*.

With its unprecedented Prototype Debug Tool, Prism is the first logic analyzer to let you set breakpoints, patch registers and memory, restart the system, and more —without an emulator's intrusiveness (or the long wait for new emulator availability).

Use real-time performance analysis to get a true, non-statistical view of system performance.

Designers of embedded control systems will especially benefit from histograms of uncompromising accuracy.

Complete front panel controls are included on the Prism keyboard, enabling users to move easily from one Prism mainframe to another.

Choose from a stand-alone version, expandable mainframe-and-monitor, even a portable model with fold-up flat panel screen.

Features like autoload, split-screen displays, smooth scrolling, automatic timestamping and on-line help notes make Prism refreshingly simple to learn and use.

The clincher? You can step into this new generation of logic analyzers at prices starting at $8600.

Call 1-800-426-2200 for our free video demo and literature packet. Prism breaks so much new ground and offers so much to build on, you owe yourself a look. For a hands-on introduction, call your Tek sales engineer soon.

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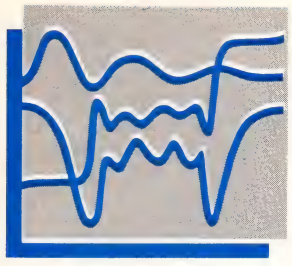
Circle 10 for Sales Contact



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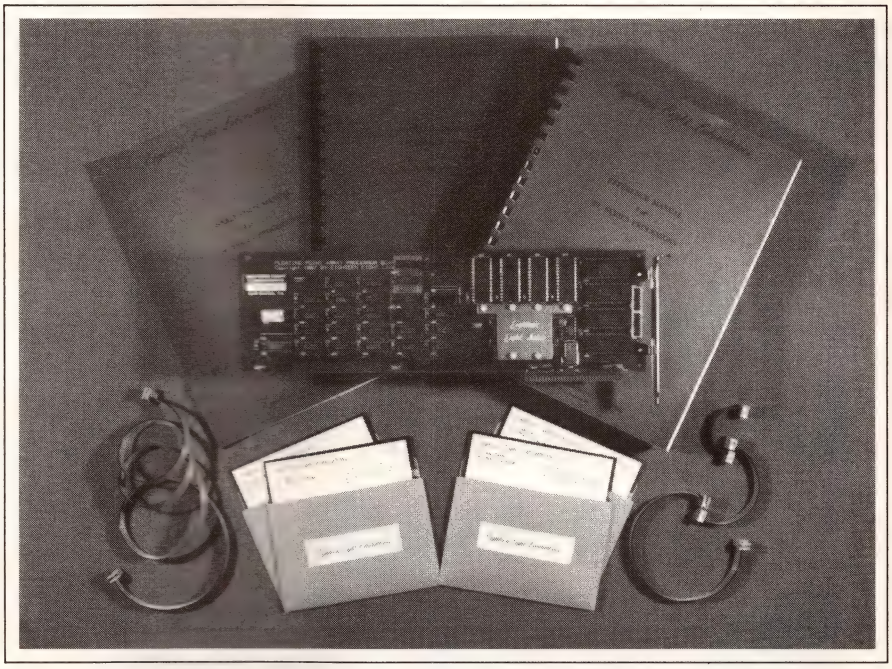
CIRCLE NO 106

NEW PRODUCTS

COMPUTERS & PERIPHERALS

ARRAY PROCESSOR

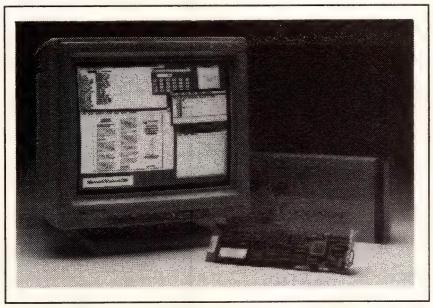
- *Delivers 12.5M flops while consuming 4.2W*
- *Performs a 1024-point complex FFT in 8.35 msec*



Designed for IBM PC/ATs and compatible computers, the PL1250 32-bit floating-point array processor has a peak performance rating of 12.5M flops and consumes 4.2W. It performs a 1024-point complex FFT in 8.35 msec and a 256×256-point real FFT in 2.25 msec. The software included with the board can manage as many as eight array processors in a single host, thereby providing a total capacity of 100M flops. The board performs all computations on data resident in its 60k-byte static RAM. In addition, the board can access the host's entire 16M-byte address space without placing the host into "protected" mode. When the computer contains more than one array processor, an operating system on each processor queues as many as 32 fundamental library routine calls. The library contains 473 microcoded functions, which are also compatible with the company's earlier products. Processor and library, $2695.

Eighteen Eight Labs, 771 Gage Dr, San Diego, CA 92106. Phone (619) 224-2158.

Circle No 351



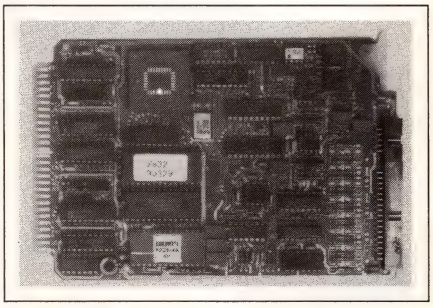
DISPLAY SUBSYSTEM

- *Consists of a 19-in. monitor and an IBM PS/2 controller board*
- *Displays two pages with 1600×1280-pixel resolution*

The Cornerstone DualPage is a display subsystem for IBM PS/2 Models 50, 60, 70, and 80 computers. The subsystem includes a 19-in. gray-scale monitor and a 200-MHz controller board that can display two pages side by side at a 1600×1280-pixel resolution. The board can refresh the noninterlaced display at 67 Hz. The system comes with the company's TrueFonts software, which uses antialiasing technology to eliminate the jagged edges common in bit-mapped fonts. This feature enables you to view on-screen text as it would appear on a laser printer. In addition, True Fonts provides Times Roman, Helvetica, Symbol, and Courier fonts. The system comes with software drivers for popular word-processing, desktop-publishing, spreadsheet, and CAD software packages. A 2-bit monochrome version, $2595; a 4- and 16-shade gray-scale version, $2850 and $3495, respectively.

Cornerstone Technology, 1883 Ringwood Ave, San Jose, CA 95131. Phone (408) 453-9800. FAX 408-453-3506.

Circle No 352



ANALOG I/O CARD

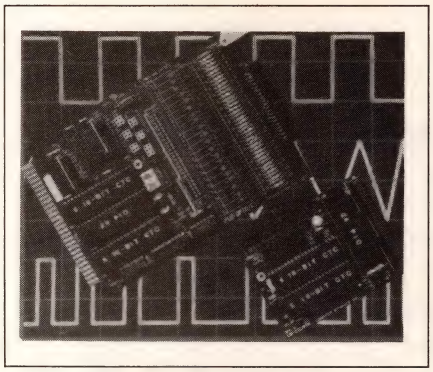
- *Has 16 analog inputs and two analog outputs*
- *Contains an 8051 μC and a 33-kHz A/D converter*

The RSD7832 analog I/O card for the STD Bus has 16 single-ended analog inputs (eight differential), two analog outputs, eight digital outputs, a serial I/O port, a CMOS 8051 μC, 64k bytes of EPROM, and 32k bytes of RAM. The analog inputs have voltage ranges from ±25

mV to ±10V and have voltage protection to ±32V. Its 12-bit A/D converter has a 33-kHz throughput rate; you can optionally increase the rate to 59 kHz. Its 12-bit D/A converter has a maximum update rate of 45 kHz and a minimum slew rate of 5V/μsec. The card also features a bidirectional 128-byte FIFO buffer interface for transferring data to and from the card. In addition, each of the 16 input channels has a space to install a lowpass filter for noise reduction. $595.

Robotrol Corp, 925 W San Martin Ave, San Martin, CA 95046. Phone (408) 683-2000.

Circle No 353



COUNTER BOARDS

- *For the STD and SBX buses*
- *Feature 10 16-bit counter/timers*

The PIO-OPTO/CTC is a counter/timer, parallel-I/O board for the STD Bus; it has 20 optically isolated or TTL inputs. The CDX-CTC/PIO is a similar board for the SBX bus; it contains 24 TTL-compatible I/O lines. Both boards feature two 9513A counter/timer chips to provide 10 16-bit counter/timers for waveform generation, frequency counting, and period measurements. Both boards have pull-up resistors on all inputs, which simplify interfacing. The input ports for the STD Bus board can accept ac or dc signals. You can individually jumper each port to accept inputs in the TTL to 12V or 6 to 24V range. The SBX module contains an 8255 parallel-I/O chip, which provides 24 programmable parallel-I/O lines. PIO-OPTO/CTC, $425; CDX-CTC/PIO, $277 (OEM qty).

Computer Dynamics Sales, 107 S Main St, Greer, SC 29651. Phone (803) 877-8700.

Circle No 354

REAL-TIME COMPUTER

- *Uses a 68020 μP operating to 20 MHz*
- *An ASIC provides message passing, DMA, mailbox interrupts*

The CPU-26 real-time single-board computer for the VMEbus uses a 68020 μP and a 68882 floating-point unit operating at 12.5, 16.7, or 20 MHz. It also utilizes an ASIC to provide message passing, mailbox

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We draw on your imagination.™

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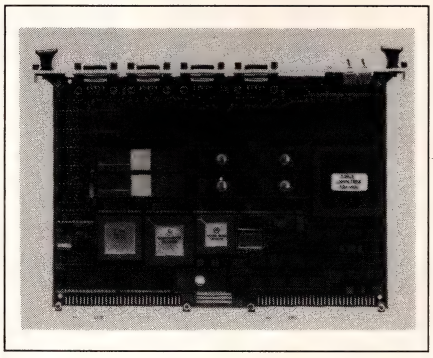
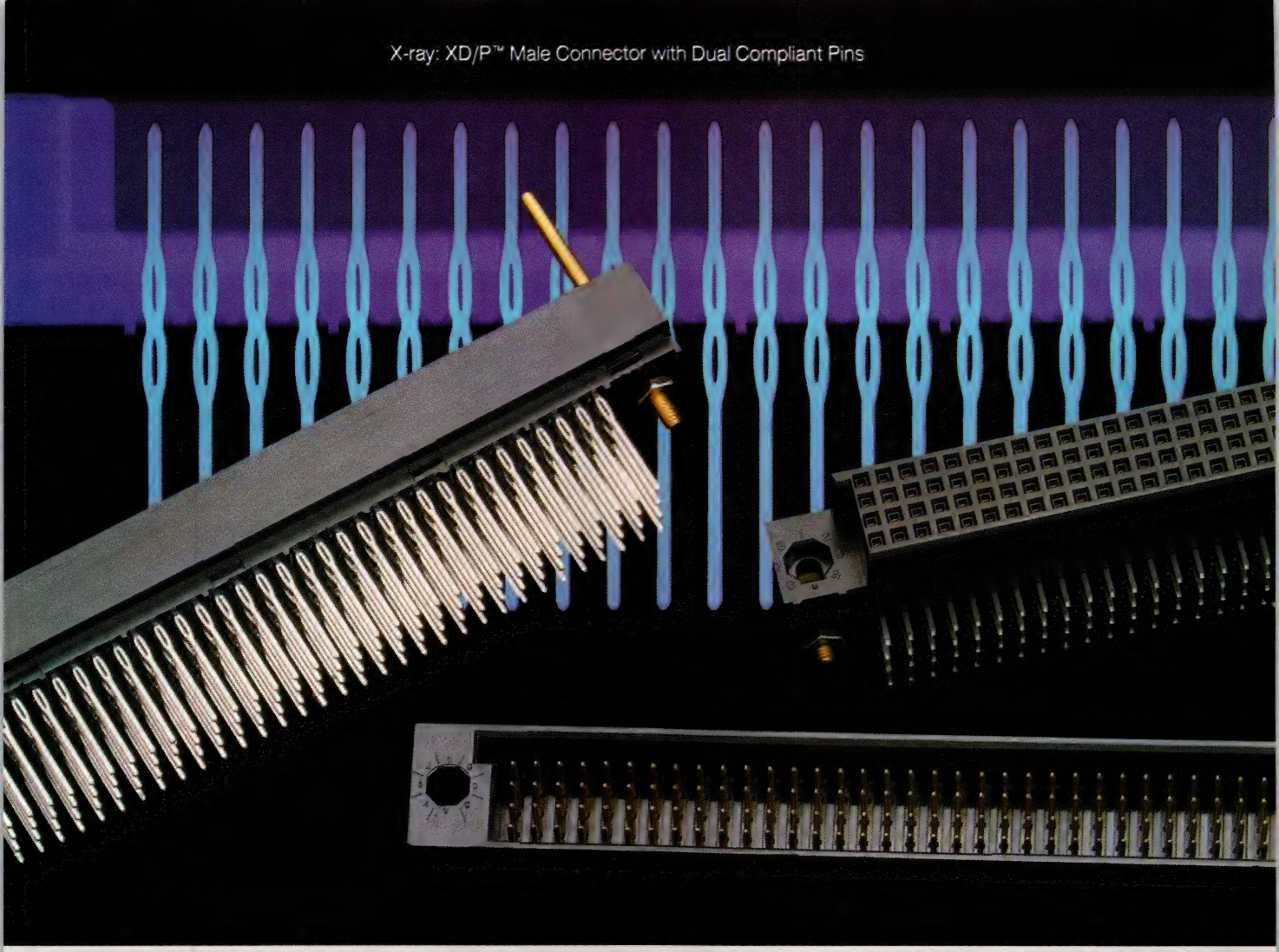
CIRCLE NO 108

COMPUTERS & PERIPHERALS



interrupts, DMA, and VMEbus interfaces. The board employs an 8-bit, 8-byte-deep FIFO message buffer and an 8-bit-wide high-priority message register. The byte-wide configuration enables the passing of 256 messages. Any VME master can deposit a message in the buffer or register. In addition, the board augments the seven hardware interrupts on the VMEbus with eight software mailbox interrupts. The board's software includes the company's VMEPROM



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Easier board-to-board insertion

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installed in EPROM, which provides a real-time operating-system kernel. It also includes a Fujitsu MB87030 SCSI controller, a Western Digital WD1772 floppy-disk-drive controller, two 24-bit and four 8-bit timers, and two 68562 dual universal serial-communication controllers. A 12.5-MHz 68020 and 68882 board with 1M byte of memory and floppy and SCSI controller, $4990.

Force Computers GmbH, Prof-Messerschmitt-Strasse 1, D-8014 Neubiberg, Munich, West Germany. Phone (089) 608140. FAX 089-6097793.

Circle No 355

Force Computers Inc, 3165 Winchester Blvd, Campbell, CA 95008. Phone (408) 370-6300. FAX 408-374-1146.

Circle No 356

MICROCONTROLLER

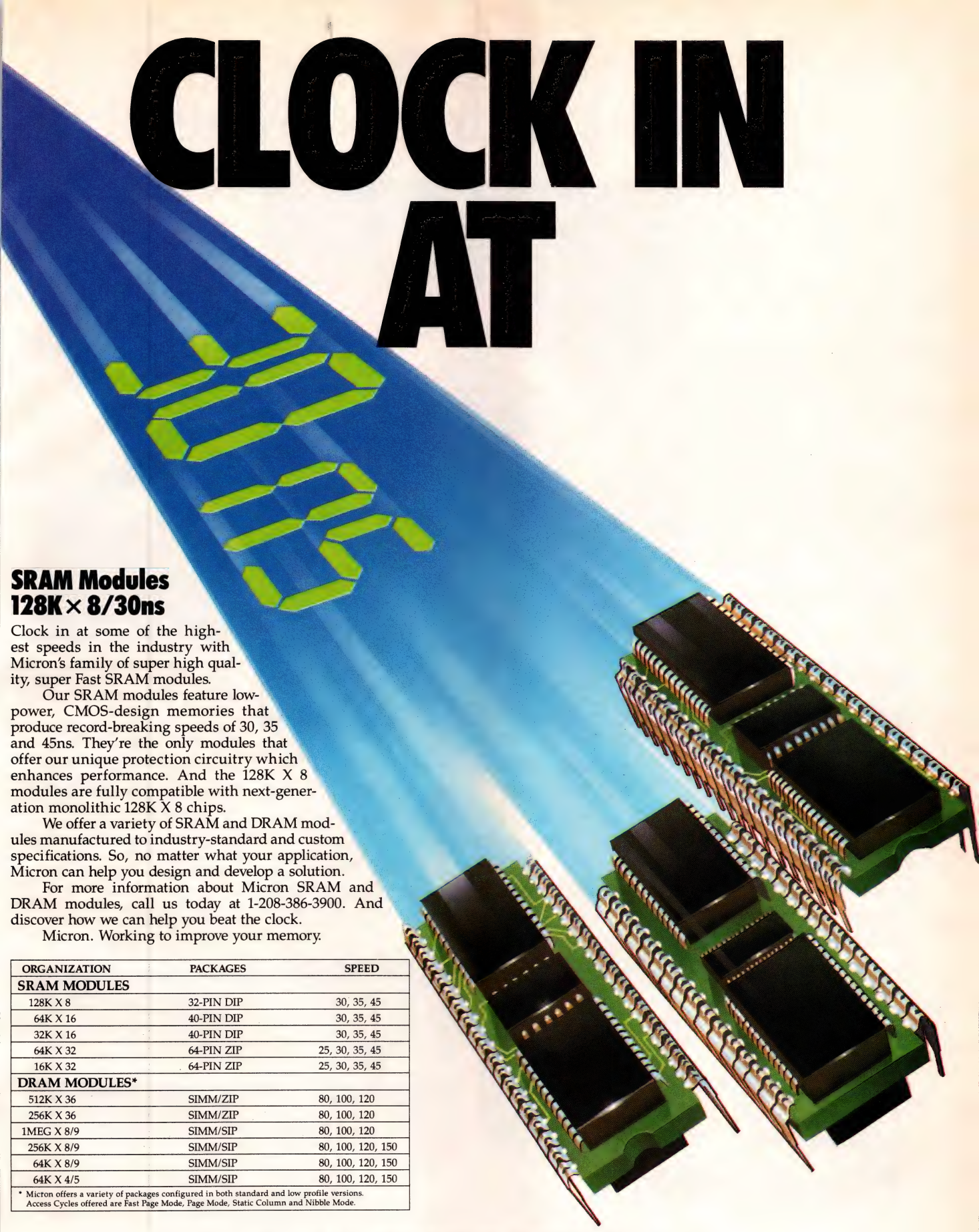
- *Board has an 80C52-Basic μC and 64k bytes of RAM*
- *Contains a Basic interpreter and operates from dc to 12 MHz*

The RTC52 microcontroller board comes in a 3½×3½-in. form factor. The all-CMOS board uses the company's 80C52-Basic μC, which is a CMOS equivalent of Intel's 8052AH-Basic μC. The board operates from dc to 12 MHz and contains a Basic interpreter. It provides 64k bytes of RAM or EPROM, a 12-bit TTL parallel port, and an RS-232C/RS-485 serial port. A stacking-bus architecture allows you to stack other boards in the company's RTC series such as A/D, D/A, parallel-I/O, and serial-I/O boards. You can also network the board to other RTC controllers or MS-DOS microcomputers using the company's MC-NET control-networking software. $99 (100).

Micromint Inc, 4 Park St, Vernon, CT 06066. Phone (203) 871-6170. TLX 643331. FAX 203-872-2204.

Circle No 357

CLOCK IN AT



SRAM Modules 128K × 8/30ns

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64K X 16	40-PIN DIP	30, 35, 45
32K X 16	40-PIN DIP	30, 35, 45
64K X 32	64-PIN ZIP	25, 30, 35, 45
16K X 32	64-PIN ZIP	25, 30, 35, 45
DRAM MODULES*		
512K X 36	SIMM/ZIP	80, 100, 120
256K X 36	SIMM/ZIP	80, 100, 120
1MEG X 8/9	SIMM/SIP	80, 100, 120
256K X 8/9	SIMM/SIP	80, 100, 120, 150
64K X 8/9	SIMM/SIP	80, 100, 120, 150
64K X 4/5	SIMM/SIP	80, 100, 120, 150

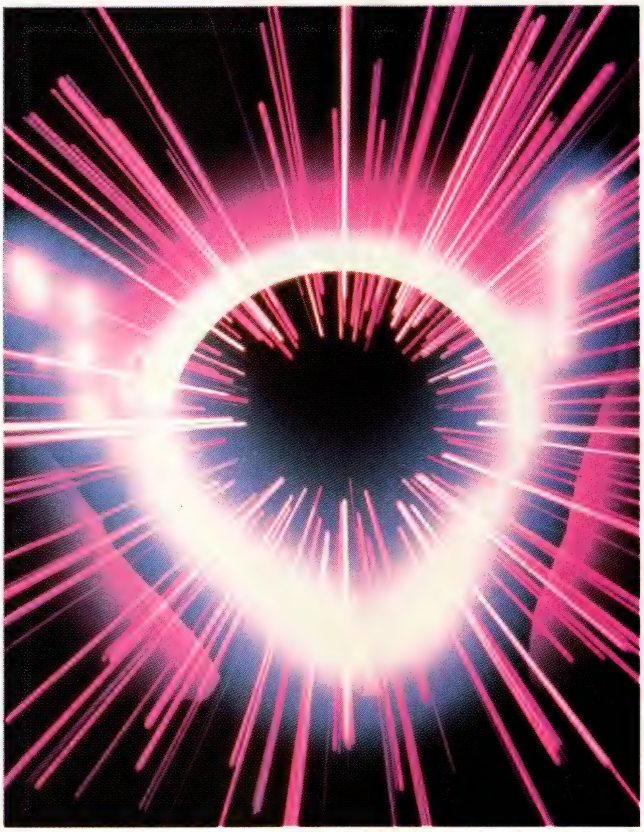
* Micron offers a variety of packages configured in both standard and low profile versions. Access Cycles offered are Fast Page Mode, Page Mode, Static Column and Nibble Mode.

MICRON TECHNOLOGY, INC.

2805 E. Columbia Road, Boise, Idaho 83706 208-386-3900

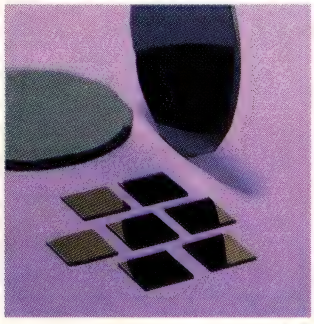
CIRCLE NO 112

Crystals for Demanding Needs



Garnet LPE film for optical isolators

Laser diodes are a critical light source for optical communications and memories, but noise generated by outside reflected light can cause a significant drop in performance. TOKIN's **Garnet LPE (Liquid Phase Epitaxy) Film**, with its superior magnetooptical characteristics,



makes an outstanding Faraday rotation isolator to prevent light from reflecting back to the diode. And it's one of many Tokin crystal products designed to meet your needs.

Acoustooptic modulation medium

TOKIN's **Tellurium Dioxide Single Crystal** (TeO_2) is the perfect material for acoustic modulators and deflectors, a key component of laser printers, color scanners and spectrum analyzers. With an optically transparent wavelength of 0.35 ~ 5 μm, it is ideally suited to modulation and deflection of visible light lasers (such as He-Cd laser [441.6 mm]).

For acoustooptic light deflectors in laser printers, facsimiles and other recording equipment, TOKIN offers **Lead Molybdate Single Crystal** ($PbMoO_4$). This

material permits higher frequencies, a wider bandwidth, high diffraction efficiency and high temperature stability—all of which add up to high-speed deflection. Yet another Tokin crystal product with an avid following.

Call us now.

• Garnet LPE Films for optical isolator (1.3 and 1.55 μm)

Composition	$(GdBi)_3(FeAlGa)_5O_{12}$	$(TbBi)_3Fe_5O_{12}$
Faraday rotation angle (deg.)	45±0.5	45±0.5
Insertion loss (dB/45°)*	≦0.3	<0.4
Change of Faraday rotation by temperature (deg./K)**	0.08	0.04
Extinction ratio (dB)*	>35	>35
Field for saturation magnetization (Oe)	~200	~700

* With anti-reflection coat ** Wavelength at 1.3 μm

• Garnet LPE Films for magnetic sensor (0.8 μm)

Composition	$(RBi)_3Fe_5O_{12}$ R: Rare-earth elements
Verdet constant (deg./Oe)	2×10^{-2}
Insertion loss (dB/45°)*	<2~3
Field for saturation magnetization (Oe)	~1500

* With anti-reflection coat, magnetic garnet film = 30 μm.

TOKIN

Tokin Corporation
Hazama Bldg., 5-8, Kita-Aoyama 2-chome, Minato-ku, Tokyo 107, Japan
Phone: 03-402-6166 Fax: 03-497-9756 Telex: 02422695 TOKIN J

Tokin America Inc.
155 Nicholson Lane, San Jose, California 95134, U.S.A.
Phone: 408-432-8020 Fax: 408-434-0375
Chicago Branch
9935 Capitol Drive, Wheeling, Illinois 60090, U.S.A.
Phone: 312-215-8802 Fax: 312-215-8804

Tokin Electronics (H.K.) Ltd.
Room 806 Austin Tower, 22-26A Austin Avenue,
Tsimshatsui, Kowloon, Hong Kong
Phone: (3) 679157 ~ 9 Fax: (3) 7395950
Taiwan Liaison Office
7/F-2, No.200, Sec.3, Hsin-Yi Road, Taipei
Phone: (02) 7059310 ~ 1 Fax: (02) 7015650

München Liaison Office
Elisabethstraße 21, 8000 München 40, Bundesrepublik Deutschland
Phone: (089) 271 75 22 Fax: (089) 271 75 67
Telex: 5 24 537 tokin d

You can reach our agents by phone: Denmark (03) 63 3830; France (1) 45-34-7535; Italy (0331) 67-8058; Spain 729-1155; Switzerland (01) 830-3161

NEW PRODUCTS

COMPONENTS & POWER SUPPLIES

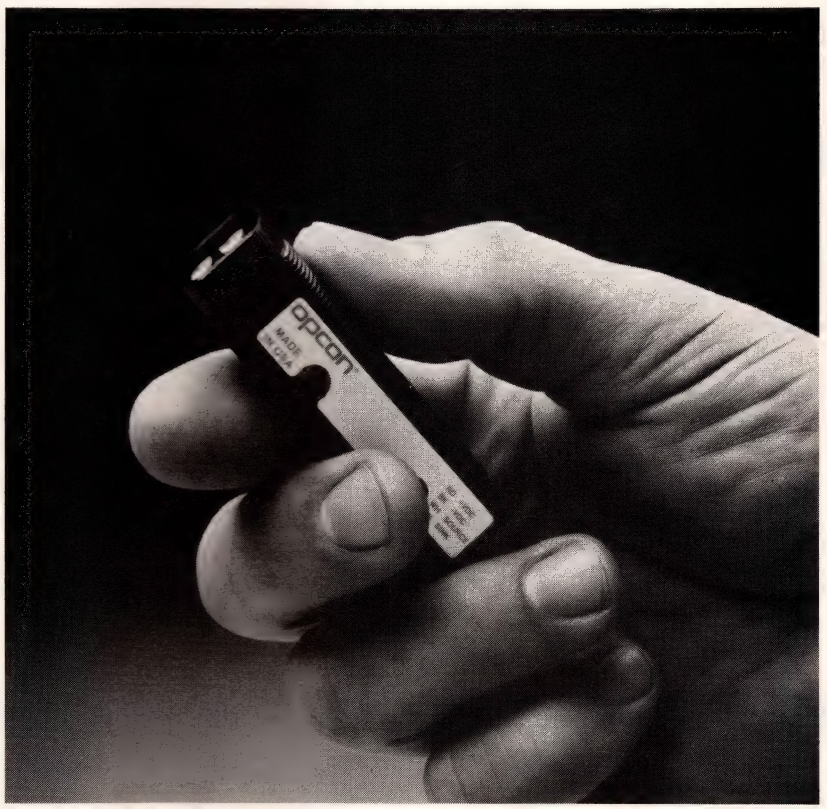
SENSORS

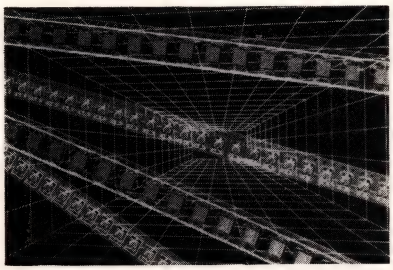
- *Operate in harsh environments*
- *Work on ac or dc*

Comet photoelectric sensor circuitry is embedded in an impenetrable plastic package, allowing the units to work in the harshest environments. The units are available in nine off-the-shelf versions: proximity mode sensors with 8- and 24-in. detecting distances; Perfect Prox mode sensors with 2- and 9-in. detecting distances; reflex mode sensors with infrared and red light sources; a polarized reflex mode sensor; fiber-optic sensors; and a through-beam sensor. All models except the through-beam unit are available in either ac/dc or dc-only versions. The through-beam sensor is available in dc-only versions. AC/DC versions, $100 to $125; dc-only versions, $70 to $125.

Opcon Inc, 720 80th St SW, Everett, WA 98203. Phone (206) 353-0900.

Circle No 358





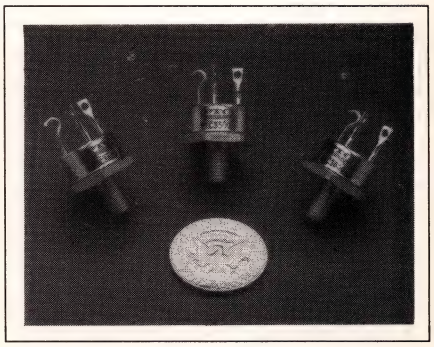
TRIMMERS

- *Designed for surface-mount applications*
- *Operate to 125°C*

Designed for surface-mount applications, ST-5 0.25-in.-square trimmers can withstand vapor-phase reflow cycles as high as 215°C for 3 minutes. They are also sealed to accommodate board washing procedures. Resistance values range from 10Ω to 2 MΩ. Other specs include a 250-mA power rating, a 200V dc operating voltage, a −55 to +125°C operating range, and a rotational life of 200 cycles with a maximum shaft torque of 200 g-cm. The trimmers are available in tape-and-reel packaging, which provides 500 pieces per reel. Shock and vibration figures equal 100 and 20g at 10 to 2000 Hz, respectively. $1.95 (5000).

Mepcopal Co, 11468 Sorrento Valley Rd, San Diego, CA 92121. Phone (619) 453-0332.

Circle No 359



TRANSISTORS

- *Rated for 60A*
- *Switch off in 2 μsec*

PTC3000 Series devices are high-voltage, high-current, fast npn transistors. The PTC3400, 3500, and 3600 are rated to handle currents of 40, 50, and 60A, respectively. All three units have a 600V rating. At rated currents, storage times for the 3400, 3500, and 3600 equal 1.5 μsec, and fall times equal 500 nsec. All units are encapsulated in TO-63 stud packages and have a thermal resistance of 0.44°C/W and a power dissipation of 400W. The

transistors are available tested to MIL-STD-750 specifications. $45 to $68 (100).

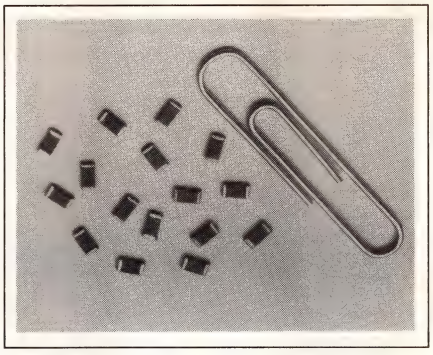
Power Technology Components, 23201 S Normandie Ave, Torrance, CA 90501. Phone (213) 534-3737. TLX 664276. FAX 213-530-5609.

Circle No 360

CHIP RESISTORS

- *Feature 0.1% tolerance*
- *Resistance values range to 100 kΩ*

TNPW1206 Model chip resistors feature a 0.1% tolerance and are available with resistance values ranging from 49.9Ω to 100 kΩ. Versions are also available with 0.5% tolerance. The units are reflow solderable and available on 8-mm reel packaging that's compatible with automatic placement equipment. Power rating equals 125 mW



at 70°C, and maximum operating voltage is 100V. Over an operating range of −55 to +150°C, temperature coefficient equals ±25 ppm/°C. To enhance reliability, the wraparound end terminations feature a nickel barrier covered by a solderable coating that protects the inner electrode. $0.55 (10,000). Delivery, stock to eight weeks ARO.

Dale Electronics Inc, 1122 23rd St, Columbus, NE 68601. Phone (402) 371-0080.

Circle No 361

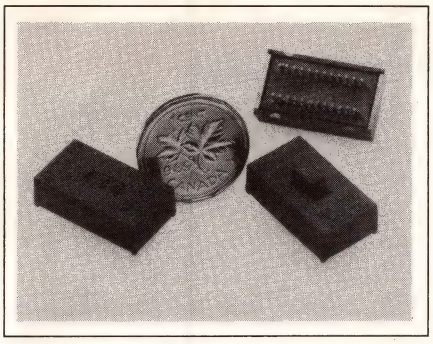
OPTOCOUPLER

- *Rated for 600V at 2A*
- *Triggers with only 4-mA inputs*

The IL428 is rated for 600V at 2A and is housed in a SIP. It consists of a GaAs infrared LED optically coupled to a nonzero-crossing triac network, which consists of two inverse parallel-connected monolithic SCRs. The 600V blocking-voltage rating allows the unit to control offline voltages as high as 240V ac. Static and commutating dv/dt equal 10,000V/μsec, and input-to-output withstand test voltage equals 7500V ac pk. Typical trigger current measures 4 mA, enabling the direct logic drive to control loads as high as 750W. No heat sink is required for 2A operation. $4.93 (1000).

Siemens Components Inc, 19000 Homestead Rd, Cupertino, CA 95014. Phone (408) 725-3405.

Circle No 362



BYTE-WIDE SWITCH

- *Satisfies high-density packaging needs*
- *Available in two versions*

The HDMP-8 is an 8-pole double-throw compression-indexed snap-action switch with gold-plated stressed elliptical contacts. The contact mechanism has fewer parts than conventional double-throw switches, allowing the unit to be built into a high-density package with 0.05-in. pin spacing. The 5-mΩ contact resistance is transparent to circuit operation. The switch is well suited for routing a digital byte or as many as eight analog signals. Two versions are available: the HDMP-8 has an actuator knob, and the low-profile HDMP-8B (0.25-in. above-board height) has a screwdriver slot. $6.50 (100).

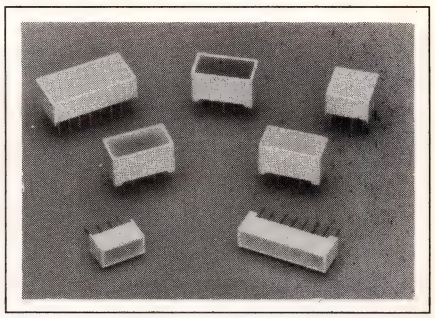
Annulus Technical Industries Inc, Box 7407, Ancaster, Ontario, Canada L9G 4G4. Phone (416) 648-8100. FAX 416-648-8102.

Circle No 363

LED LIGHT BARS

- *Contain as many as eight LED chips*
- *Available in three colors*

Series LTL-2000 LED light bars are available in six sizes—0.5×0.25, 0.35×0.15, 0.75×0.15, 0.35×0.35, 0.35×0.75, and 0.35×0.15 in. Depending on size, the light bars contain anywhere from two to eight LED chips. Choice of colors includes high-efficiency red, high-efficiency green, and amber yellow. Brightness figures range from 5 to 10 mcd at 10 mA. All the light bars are designed to mount directly on pc boards or in standard DIP sockets. $0.72 (1000) for 0.35×0.15-in. unit. Delivery, stock to six weeks ARO.



Ledtronics Inc, 4009 Pacific Coast Hwy, Torrance, CA 90505. Phone (213) 549-9995. FAX (213) 549-4820. TLX 4915454.

Circle No 364

COMPONENTS & POWER SUPPLIES

ATTENUATORS

- *Have a 1- to 20-dB attenuation range*
- *Available in DIP, TO-5, or chip packages*

Units in this family of fixed-pad attenuators are available in TO-5, DIP, and surface-mount chip versions. The TO-5 and DIP units are designed for pc-board mounting and have a 1.35:1 VSWR; chip devices are designed for stripline or microstrip technology and have a 1.1:1 VSWR. All units are available in values ranging from 1 to 20 dB. They exhibit an accuracy of 0.2 dB or 2% of nominal value and operate over a range of dc to 1 GHz. Because the devices are constructed of thick-film alumina, they can dissipate more power than comparably sized thin-film devices. TO-5 and DIP units, $14; chip versions, $4 (1000).

Telonic Berkeley Inc, Box 277, Laguna Beach, CA 92652. Phone (714) 494-9401. FAX (714) 497-7331.

Circle No 365

DC/DC CONVERTERS

- *Designed for the military market*
- *Output either 10 or 20W*

Available with either single or dual outputs, these dc/dc converters have outputs of 10W for the 9010 Series and 20W for the 9020 Series. Featuring power densities of 2.5 and 5W/in.^{3}, respectively, the converters operate on inputs of 18 to 32V and output levels ranging from 5 to 24V. Efficiencies equal 70% min, and the switching frequency measures 350 kHz. Isolation equals 100V between input and output and between input/output and case. The converters feature overvoltage protection as standard and operate over a −55 to +100°C range. $695 to $805 (100). Delivery, 26 weeks ARO.

Tecnetics Inc, Box 910, Boulder, CO 80306. Phone (303) 442-3837. TWX 910-940-3246.

Circle No 366

Optrex Single Cell, Black and White Displays. An Important Advancement in LCD Technology.

- ☐ Blacker Blacks
- ☐ Whiter Whites
- ☐ Less Power
- ☐ Less Weight
- ☐ Thinner Design
- ☐ Lower Cost

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your bright new ideas
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Optrex Corp. A Joint Venture By Asahi Glass & Mitsubishi Electric

CIRCLE NO 90

FULL SPE

For the name of your nearest distributor in Europe, call 44-296-625462. Or contact Applied Microsystems Corporation Ltd., Chiltern Court, High Street, Wendover, Aylesbury, Bucks HP22 6EP, United Kingdom. **In Japan, call 03-493-0770.** Or contact Applied Microsystems Japan Ltd., Nihon Seimei, Nishi-Gotanda Building, 7-24-5 Nishi-Gotanda, Shinagawa-KU, Tokyo T141, Japan. AMC 240

ED AHEAD.

INTRODUCING THE FIRST 33-60 MHz MICROPROCESSOR EMULATOR FOR THE 68020 AND 68030.

Put your phone in front of you and get ready. You're about to get in touch with the future of high speed microprocessor emulation.

For quite some time Applied Microsystems has been designing a radical new concept in 32-bit development. Now it's ready. The EL 3200.

It's capable of not only matching current speeds, but can efficiently expand to support faster speeds and advanced 32-bit microprocessors of the future.

The news is not just speed, but how the EL 3200 gets up to speed.

It runs at full target clock speed—33 MHz for 68020 and 68030. It fully supports 68030 cache burst and synchronous bus cycles. And, since it sits as a node right on the trunk of your Ethernet network, the EL 3200 can be accessed from any workstation.

The EL 3200 offers your choice of source level or symbolic debugging. Whether you want to work in Assembly or C, we can provide the software tools for your exact needs.

The sophisticated breakpoint system has hundreds of real-time access breakpoints, six real-time execution breakpoints and unlimited software execution breakpoints. As an option, you can have up 2MB of no wait state overlay memory that runs at full clock speed, so there are no restrictions on memory, software or interrupts. The 16K deep by 139 bit wide trace provides true 32 bit support.

Seeing is believing. For a demonstration or more information, pick up your phone.

Dial full speed ahead and ask for Telemarketing. In WA (206) 882-2000.

Applied Microsystems Corporation, P.O. Box 97002, Redmond, Washington, USA 98073-9702.

1-800-343-3659

Applied Microsystems Corporation

CIRCLE NO 117

Their way.

Our way.

Here's how to turn a relay with 2 changeover contacts into one with 4.

The MT4, our new relay with 4 changeover contacts, hardly occupies more board space than the MT2, our relay with 2 changeover contacts.

So if you need 6 twin changeover contacts on your board, simply install an MT2 and an MT4. Two relays of virtually identical size.

And the expensive space you formerly needed for a third MT2 is now free for other important functions.

Plus: less testing, less component cost, less assembly effort, greater reliability.

What more can you want?

(The new MT4: Power consumption at 20°C 300 mW. Temperature range −55°C to 85°C. Space occupied per contact 12 M^2.)

I'm interested in the new MT4 relay. Please send me your literature. **EDN 14 • 09 • 89**

Company _____

Name _____

Address _____

_____

Telephone _____

Standard Telephon und Radio AG
CH-8055 Zurich/Switzerland, Friesenbergstrasse 75

ALCATEL

STR

CIRCLE NO 118

Dr. Juchli 924 STR

PANDUIT® LAT-CON™ Connector System

Lateral is Logical

Lateral entry *increases your output up to 400%*, by eliminating rework and scrap *without* increasing labor costs.

That's why it's logical to terminate .050″ flat cable with LAT-CON connectors. In this unique system, the cover and socket are supplied joined on one side with the opposite side open. This permits *fast and accurate* lateral entry and termination of the flat cable when used with Panduit's unique, inexpensive tooling.

And the patented design makes it logical to use the *same connector* for both end and daisychain terminations, allowing you to cut your inventory costs and boost your productivity.

Panduit's logical LAT-CON system gives you all these benefits:

- Broad line of .050″ products, including sockets, card edge and transition connectors; three styles of headers.
- Selective gold or tin plating options on high quality contacts.
- Applicable products U.L. recognized and MIL-C-83503 Intermateable.
- Custom coding available without loss of contact.
- Full line of time-saving termination tooling, including high volume reel-fed system... designed to lower your installed cost.

Be logical—go lateral. Call today for FREE Samples or a Productivity Improvement Demonstration.

1-800-323-2428 (In Illinois 1-312-887-1000)

PANDUIT CORP

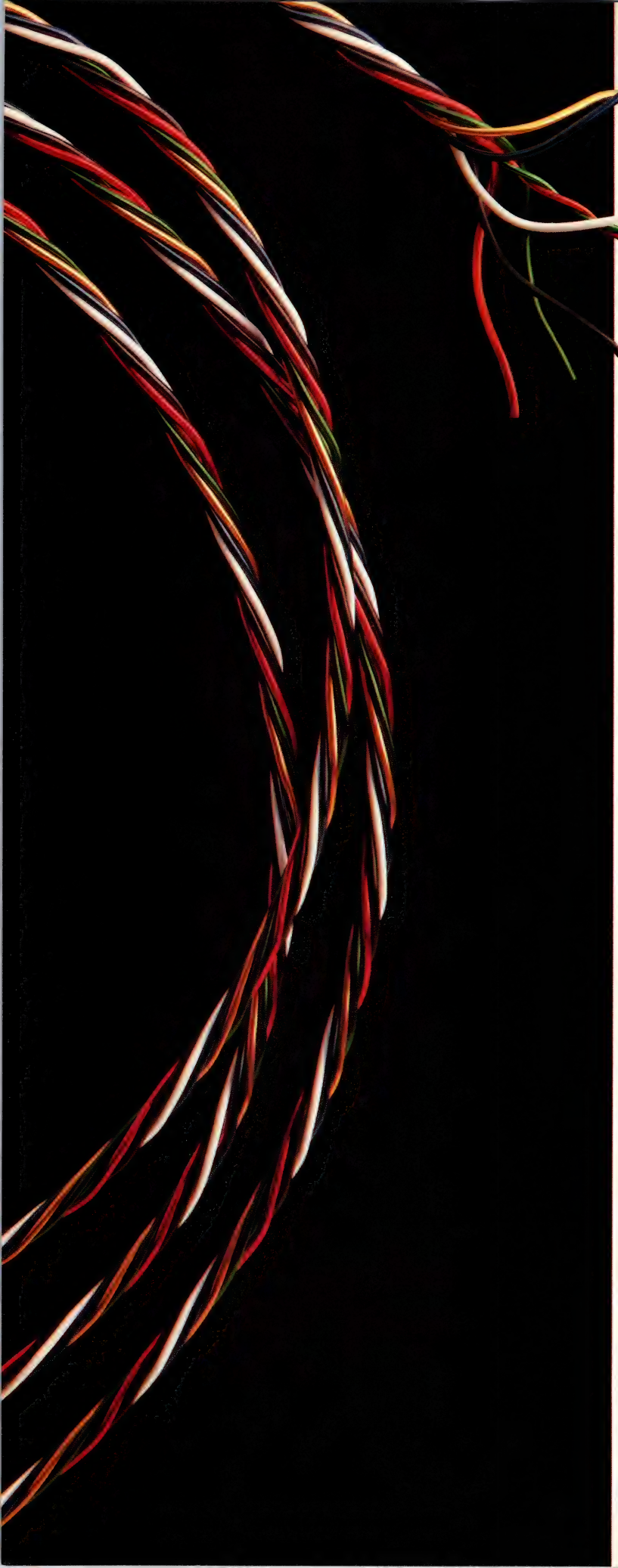
ELECTRONICS GROUP

Tinley Park, IL 60477-0981

In Canada: Panduit (Canada) Limited

CIRCLE NO 119

Visit PANDUIT at the ASSEMBLY TECH SHOW, Booth 2107



TWISTITE™

MAGNET WIRE

For superior performance and tighter control over twisted wire construction.

Developed for use in the production of custom toroid, ferrite or recording head coils, specialty audio and R.F. transformers, TWISTITE offers a number of distinct advantages.

TWISTITE is custom produced to offer a wider range of twisting construction. Manufacturing capabilities include:

- Up to 33 Twists Per Inch on fine wire.
- Twisting tolerance as tight as ±1%.
- Tightly controlled capacitance, inductance and impedance characteristics.
- Up to 10 colors in some sizes for conductor identification.
- Huge selection of insulations: NEMA MW 1000, JW1177, 105–220°C (single through quadruple film builds).
- Wide range of sizes: 24 AWG and finer.
- Wide variety of conductor materials: copper, silver, plated conductors, and special alloys.

Call or write for your free copy of our Technical Data Booklet and Capabilities Brochure. Both contain valuable information on all wire produced and inventoried by MWS Wire Industries. Samples of TWISTITE are available upon request.

MWS

Wire Industries

31200 Cedar Valley Drive, Westlake Village, CA 91362

CALL TOLL FREE 800 423-5097

In California 800 992-8553. In L.A., 818 991-8553

TWISTITE™ is a trademark of MWS Wire Industries

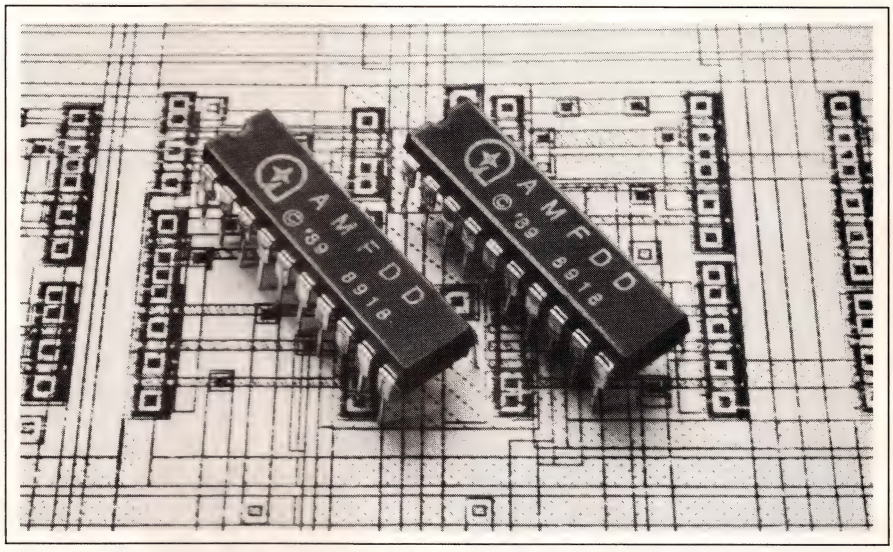
CIRCLE NO 121

NEW PRODUCTS

INTEGRATED CIRCUITS

DISPLAY DRIVER

- *Drives two 7-segment LEDs*
- *Used to indicate PC operating speed*



The AMFDD frequency display driver contains two 7-segment LED drivers for use in a 2-digit, floating-point display of a personal computer's operating frequency. Designed for use in computers with multiple system-clock frequencies, the complete display unit with the autoswitching FDD chip will display a frequency range of 0.1 to 39 MHz. The display unit need only consist of two common-anode LEDs, two resistor packs, and an FDD chip. The FDD continuously samples the system clock and automatically reconfigures itself to display the correct frequency, without the need to change jumper settings in the PC. The input to the display unit consists of four lines that interface with the system clock, reference clock, and the power signals. 20-pin DIP, $4.95 (100).

Amax Applied Technology Inc, 3001-A W Mission Rd, Alhambra, CA 91803. Phone (818) 300-8828. FAX 818-282-9992.

Circle No 367

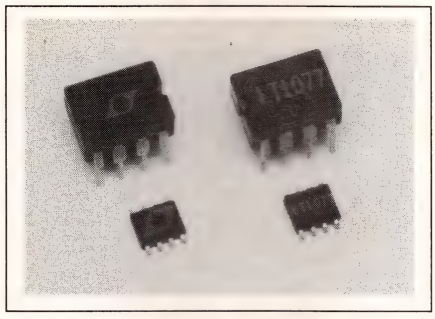
MOSFET DRIVER

- *Adaptive circuit provides protection*
- *Has an emitter-follower output*

The Si9910 is a single-channel, noninverting driver that adapts to the operating conditions of the power-driven MOSFET, thus providing protection for the MOSFET while optimizing the gate drive. Designed to drive a wide range of power MOSFETs in motor-control applications, the Si9910 contains a Schmitt trigger input and a low-impedance, emitter-follower output. On-chip circuitry protects the MOSFET against excess dv/dt and di/dt, undervoltages, and overcurrent conditions by monitoring the operating conditions via feedback loops and altering the drive output. The driver is specified for operation over the industrial temperature range and comes in an 8-pin DIP. $1.71 (100).

Siliconix, 2201 Laurelwood Rd, Santa Clara, CA 95054. Phone (408) 970-5200.

Circle No 368



PRECISION OP AMP

- *Operates at low current*
- *Has low offset voltage*

Optimized for operation from a single 5V supply, the LT1077 precision, micropower op amp is also fully specified for operation from a ±15V supply. Operating at a supply current of 60 μA (max), the LT1077 features an offset voltage of 40 μV (max) and an offset current of less than 0.35 pA. The op amp's 0.1- to 10-Hz peak-to-peak voltage and current noise are 0.5 μV and 2.5 pA, respectively. The gain-bandwidth product is 250 kHz. Pin compatible with other industry-standard precision op amps, the LT1077 offers 10 to 60 times lower power dissipation, according to the company. The device is available in 8-pin plastic or ceramic DIPs, 8-pin small-outline packages, and metal cans. Commercial, industrial, and military temperature ranges are available. From $1.65 (100).

Linear Technology Corp, 1630 McCarthy Blvd, Milpitas, CA 95035. Phone (800) 637-5545.

Circle No 369

GRAPHICS CHIP SETS

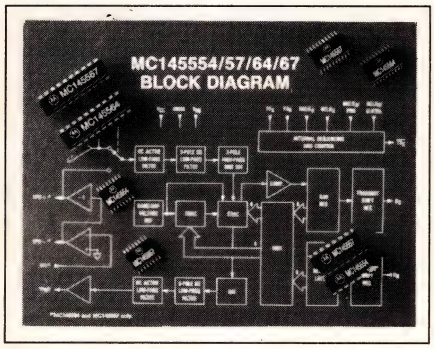
- *Provides a VGA-LCD interface*
- *Supports 64 gray shades or colors*

Designed for use in laptop computers, Dragon Graphics chip sets combine a graphics controller, a color palette, and a VGA-LCD interface. Set 1 consists of the SPC8000FOA graphics controller, the SPC8010-FOA VGA-LCD interface, and the SEA6461J35 color palette for 16 to 64 gray scales. Set 2 consists of the same graphics controller plus the SPC8030FOA VGA-LCD interface

and the SEA6462J35 color palette for a 64-color display. The graphics controller maintains register-level compatibility with IBM's VGA, EGA, CGA, and MDA graphics standards and provides 640×480-pixel resolution with 256 simultaneous colors. Both chip sets also interface with external analog and digital CRT monitors. $55 (5000) each.

S-MOS Systems, 2460 N First St, San Jose, CA 95131. Phone (408) 922-0200.

Circle No 370



PCM CODEC FILTERS

- *Suitable for Mu-Law or A-Law formats*
- *Have differential analog circuitry*

The MC145554/57/64/67 family of single-chip PCM codec filters uses a fully differential analog circuit design to achieve low idle-channel noise and high power-supply rejection. The devices, which contain an on-chip 2.5V precision voltage reference, accept industry-standard clock formats and operate in both synchronous and asynchronous applications. The MC145554/64 are for use with a Mu-Law PCM format; the MC145557/67 are used with A-Law formats. Other features include transmit band pass and receive low pass filters, active R-C prefiltering and postfiltering, a PCM-data clock rate of 4.096 MHz, and a typical power dissipation of 40 mW at ±5V. The MC145564/67 add analog loop-back and push-pull power amplifiers with adjustable gain. The 54/57 devices come in 16-pin DIPs and SOIC packages; the 64/67 devices come in 20-pin DIPs and SOIC packages. From $3.95 to $4.95 (1000).

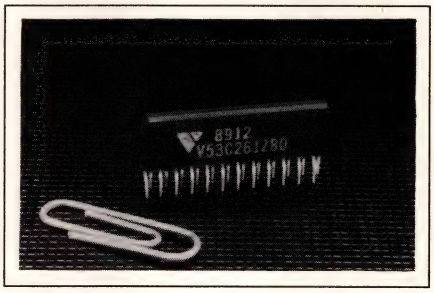
Motorola Inc, MOS IC Div, Box 52073, Phoenix, AZ 85072. Phone (512) 928-6880.

Circle No 371

VIDEO RAM

- *Clocks data at a 33-MHz rate*
- *Organized 64k×8 bits*

A high-performance 64k×8-bit video RAM, which clocks 256 4-bit words at a serial rate of 33 MHz, the V53C261 is a multiport device that features fast page-mode access. The device has a maximum address-access time of 80 nsec, a maximum column-address time of 40 nsec, and a page-mode cycle time of 55 nsec. It also has a turbo-mode feature that permits real-time read transfer during row address changes; a bit-masked write function; and bidirectional data transfer



between the serial and dynamic RAM ports. The V53C261 comes in a 24-pin plastic, zig-zag in-line package, which provides high packing density. $14.63 (100)

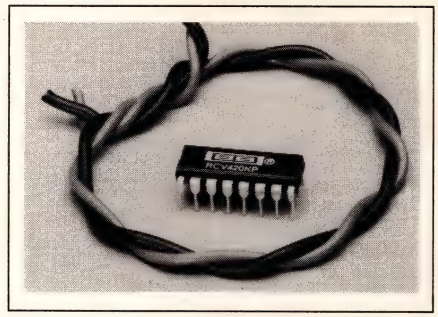
Vitelic Corp, 3910 N First St, San Jose, CA 95134. Phone (408) 433-6000. FAX 408-433-0331.

Circle No 372

CURRENT-LOOP IC

- *For 4- to 20-mA industrial loop*
- *Provides a 0 to 5V output*

The RCV420 converts 4- to 20-mA, 2-wire current-loop signals to 0 to 5V outputs signals. The monolithic device includes current-sampling



resistors, a premium-grade op amp, a level-shifting network, and a precision reference. The 10.00V reference, which is externally available to the user, has a typical drift of 5 ppm/°C. Other key specifications include a ±40V (max) common-mode input range, a conversion accuracy of 0.1% FS, and 80-dB CMR. The RCV420's wide supply range of ±11.4 to ±18.0V lets you use the device in data-acquisition systems using 15V supplies and in PC-based systems with 12V supplies. Available in 16-pin plastic or ceramic DIPs. From $4.60 (100).

Burr-Brown Corp, Box 11400, Tucson, AZ 85734. Phone (800) 548-6132. FAX 602-889-1510.

Circle No 373

BUFFER AMPLIFIER

- *Bandwidth is 180 MHz*
- *Slew rate is 2000V/μsec*

Designed for use in video applications and as an input buffer for high-speed A/D converters, the EL2002 features a −3-dB bandwidth of 180 MHz and a slew rate of 2000V/μsec. With its low output impedance of 8Ω, the device can drive 50 and 75Ω coaxial cables. The amplifier's 100-mA output can also quickly charge the varying input capacitance of high-speed flash A/D converters. The EL2002, which comes in 8-pin plastic and ceramic DIPs, 20-pin small-outline and 20-pad ceramic LCC packages, is available in industrial and military versions. From $2.45 (100).

Elantec, 1996 Tarob Ct, Milpitas, CA 95035. Phone (408) 945-1323.

Circle No 374

APPLICATION SPECIFIC PLASTICS FROM PHILLIPS 66

CONNECTING VALUE WITH PERFORMANCE

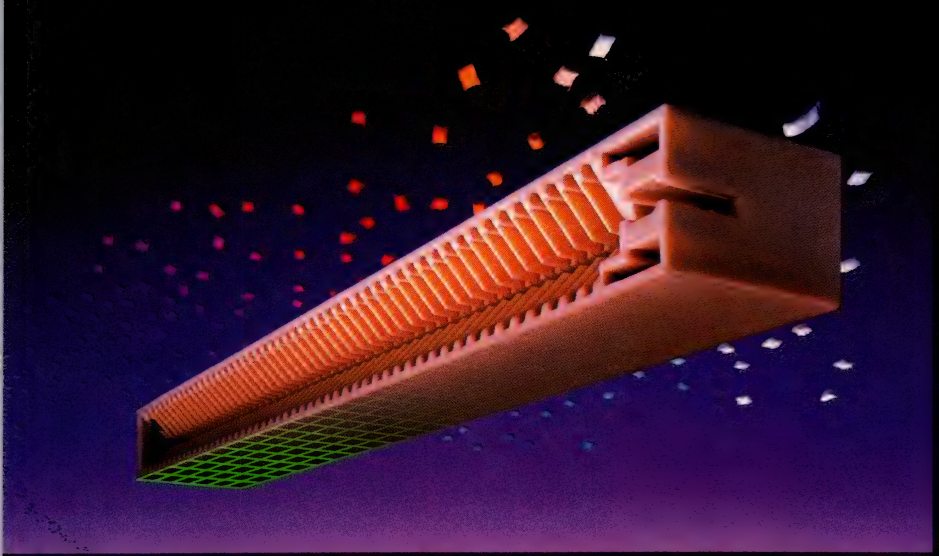
Performance and value. You can get both with Aspect™ TPPE from Phillips 66. This engineering thermoplastic polyester gives you:

- Improved flow and processability to help you mold complex, intricate parts—easily and precisely, at low injection pressures.
- Long-term thermal performance —retaining over 50% tensile strength after 17 weeks at 220° C.
- Excellent electrical properties—offering high arc resistance and low dielectric constant.

Aspect™ TPPE is ideal for applications such as high density interconnectors; thin, intricate and hard-to-mold bobbins; terminal blocks; and fuse holders.

With Application Specific Plastics such as Aspect™ TPPE from Phillips 66 you can take advantage of the expertise of the Phillips 66 Plastics Technical Center . . . its research and development and advanced molding facilities, the computer-aided design capabilities, the experienced staff, and more.

Phillips 66 offers other Application Specific Plastics for your electrical/electronic needs: Ryton® PPS, Ryton® S PPSS, and Crystalor™ PMP. For more information call toll free ***1-800-53-RESIN***. Or Telex #492455.



ASPECT™ TPPE

PLASTICS WITH POWER TO WIN™

PHILLIPS 66

CIRCLE NO 122

Prepare for Tomorrow's Technology Today

NATIONAL ELECTRONIC PACKAGING AND PRODUCTION CONFERENCE

NEPCON SOUTHEAST '89

This Fall in Orlando, Florida
Three-Day Conference, November 14-16, 1989
Two Day Exhibition, November 15-16, 1989

It's been three years since we've put on a show for you in Orlando. We feel the time is right for the nation's leading electronics manufacturers and experts to assemble again in this important growth area of the U.S.

If you're an engineer responsible for circuit and systems design, packaging, board fabrication, assembly or test, then you know the challenges of bringing a competitive product to market. Here's your chance to evaluate and test out the industry's newest technology in your own back yard.

Led by experts in their fields, Nepcon Southeast's full conference program explores the future trends of electronic technology, from design through final test and assembly, while addressing practical solutions to important "here and now" issues. The exhibition encompasses the complete product development cycle, including computer-aided technology, packaging products, and production and inspection equipment, offering hands-on demonstrations from the industry's top suppliers.

Plan now to visit NEPCON Southeast this fall. It may well be your only opportunity all year to keep pace with today's technology and trends for tomorrow. If you register before October 27, 1989, you'll be admitted FREE to the exhibits, plus earn substantial discounts on the conference. For more information, call (312) 299-9311, or mail in this coupon.

Clip and mail to:
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VF Technology... The Bright Decision

Futaba, a world leading manufacturer of vacuum fluorescent displays, offers a wide assortment of *display tubes* in many sizes and formats. Also, Futaba offers *display modules* with all the electronics required to refresh the display and easily interface with host system.

GRAPHIC DISPLAY

Both front glass phosphor, which provides maximum viewing angle and uniform surface appearance, and conventional back glass phosphor, with optimum brightness and software dimming capabilities, are available. All Futaba graphics modules offer complete drive electronics, bit mapped control with a DC/DC converter. All active components are surface mounted onto a single board.

DOT MATRIX MODULES

Utilizing Futaba's dot matrix displays, a completely intelligent line of "dot modules" is available. Each includes all drive, power supply and microprocessor components surface mounted onto a single board. Surface mounted technology results in higher reliability and allows for a smaller overall package and lower cost. All dot modules require only a 5V DC power source and can accept parallel or 8 possible serial baud rates.

GRAPHIC DISPLAYS/MODULES

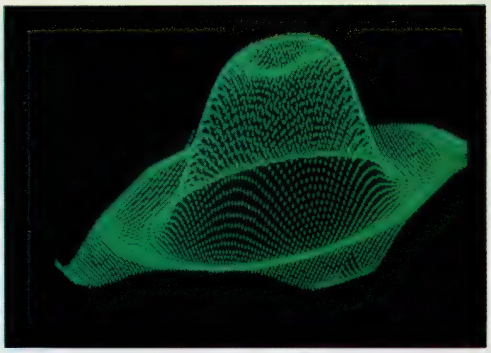
Futaba Display	Futaba Module	Pixels (Row X Char.)	Brightness (FT-L)	Module Dimensions (in.)
GP1005B	GP1005B03	128X64	400	7.28X3.35X1.77
GP1010B	GP1010B01	176X16	200	7.32X2.16X1.70
GP1009B	GP1009A04	240X64	200	6.2X2.76X1.57
GP1006B	GP1006B05	256X64	200	9.84X3.35X1.77
GP1002C	GP1002C07	320X240	100*	7.10X6.30X1.60
GP1018A	GP1018A01	400X240	40	7.10X6.30X1.61

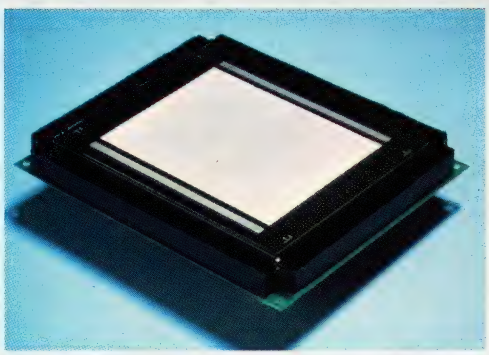
*Different Versions Available

DOT MATRIX/CHARACTER DISPLAY MODULES

Futaba Display	Futaba Module	Char. X Row	Dot Format	Char. Ht. (in.)	Module Dimensions (in.)
16LD03G	M16LD03B	16X1	5X7	0.433	8.90X1.95X.98
16SY03Z	US16SY03A	16X1	14 SEGMENT ALPHANUMERIC	0.200	4.92X1.32X.83
20SD03G	M20SD03	20X1	5X7	0.200	5.91X1.22X1.05
20SD42Z	M20SD42	20X1	5X12	0.344	7.1X2.16X.88
40SD04G	M40SD04	40X1	5X7	0.200	9.45X1.38X1.14
40SD42Z	M40SD42	40X1	5X12	0.344	9.45X2.16X.88
202SD08G	M202SD08	20X2	5X7	0.200	6.10X1.69X1.18
402SD06G	M402SD06	40X2	5X7	0.200	9.45X1.69X1.18

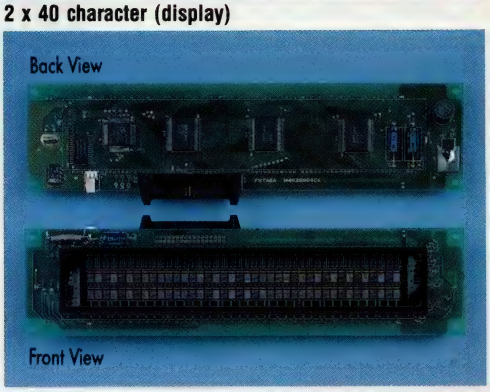
MANY OTHER DISPLAYS | NEW MODULES AVAILABLE SOON | CUSTOM VERSIONS AVAILABLE DEPTH DIMENSIONS FOR LIMITED AREA ONLY





Compact, flat panel graphic displays and modules present clean, sharp images, whether for text or full graphics application.

2 x 40 character (display)



2 x 40 character (module)

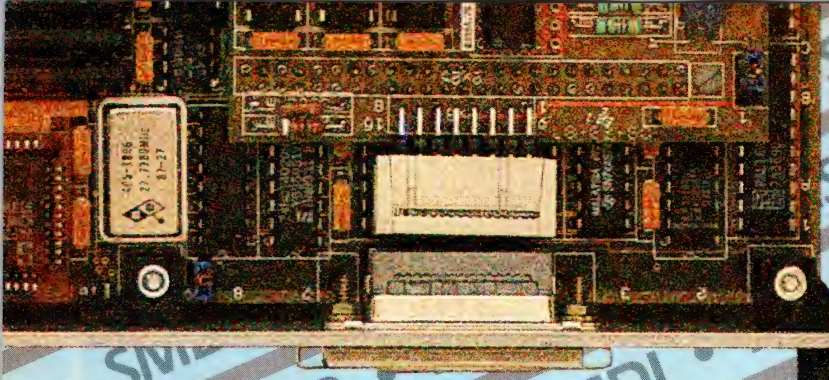
Pattern flexibility and pleasing appearance are offered by Futaba in dot displays and modules.

Futaba also offers a complete catalog of alphanumeric, segmented displays.

Futaba supports its products with design engineering and system integration assistance. Call or write today.

FUTABA
Corporation of America
Electronic Components Division
711 E. State Parkway
Schaumburg, IL 60173
Telephone: (312) 884-1444
FAX: (312) 884-1635

CIRCLE NO 123



DISK CONTROLLER SOLUTIONS

MAKING A CHOICE

System designers usually make two major choices when selecting peripheral controllers: choosing the appropriate technology, and choosing the best supplier of that technology. Interphase is the one choice that's right for both.

A CHOICE SELECTION

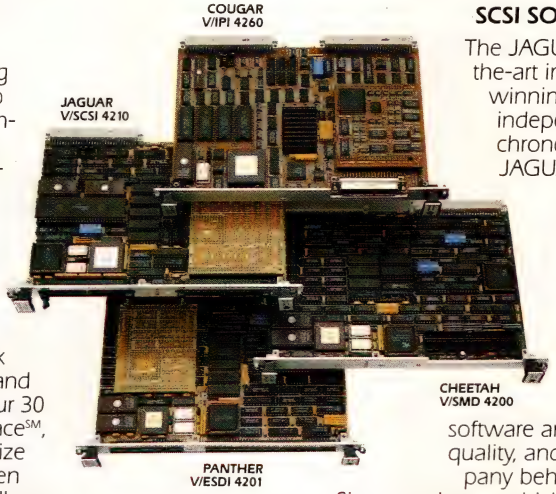
Whether your system calls for IPI, SMD, ESDI or SCSI, Interphase provides not only the highest performing controllers, but a proven approach to design support, on-time delivery, technical service and unrelenting quality. All this has made Interphase the supplier of choice by more OEMs than any other in the industry.

A GREAT CHOICE

There are many reasons why Interphase is a great choice. Our technology squeezes the last ounce of performance out of the disk drive with industry-leading caching and queuing techniques. The speed of our 30 plus MB/s VMEbus BUSpacket Interface℠, the industry's fastest, lets you maximize system performance. We actually listen to what you need, rather than just tell you what we've got. You can rely on us to help you get your system up and running, no matter what. You can count on the highest product quality and best on-time delivery in the industry.

IPI SOLUTIONS

If you're looking for the fastest disk possible, you're probably considering IPI. Our COUGAR V/IPI 4260 is the highest performance open system disk controller available today. Using a full 32-bit 68020 architecture, the COUGAR features our proprietary IPI front-end processor in combination with the exclusive Virtual Buffer Architecture℠ and VMEbus BUSpacket Interface operating at 38 MB/s.



ESDI AND SMD SOLUTIONS

The PANTHER V/ESDI 4201 and CHEETAH V/SMD 4200 are the most designed-in VMEbus disk controllers in the industry. They are still the fastest anywhere, featuring leading edge caching algorithms, command queuing techniques and our BUSpacket Interface – **any** disk drive, **any** speed!

SCSI SOLUTIONS

The JAGUAR V/SCSI 4210 established the state-of-the-art in high-performance SCSI applications – winning every benchmark in sight. With two independent SCSI ports, asynchronous or synchronous, single-ended or differential, the JAGUAR SCSI host adapter can keep all your SCSI devices busy, even including arrays of high-performance drives in file striping or data base applications. Of course the BUSpacket Interface is part of the package.

NO OTHER CHOICE

Regardless of the disk technology you choose for your system – if you want the highest performing products, the best software and technical support, the most reliable quality, and the strongest and most responsive company behind the product – you want Interphase. Since you know which vendor is the best, whether it's disk controllers, Ethernet or FDDI, all you need to do is pick the technology. To help with that choice, we've prepared a booklet comparing disk technologies. To receive a free copy, just call:

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CIRCLE NO 124

NEW PRODUCTS

CAE & SOFTWARE DEVELOPMENT TOOLS

SHELL FOR OS-9

- *Includes command-line editor*
- *Provides command-line history feature*

ZSH is an advanced shell for Microware's (Des Moines, IA) real-time, multitasking OS-9 operating system. This shell combines the outstanding features of most of the popular Unix shells; the ZSH syntax and its command-line editor closely resemble those of DEC's VMS/DCL. However, ZSH is tailored to take full advantage of the specific features of OS-9. The command-line editor permits extensive modification of a command; the history feature maintains a record of the last 19 commands; you can browse through these, modify them with the command-line editor, and then re-execute the modified commands. A symbol function lets you replace the name of any utility program with another name (alias) of your choice. The alias of a command can include redirection instructions. A Basic-like batch-control language lets you write powerful procedure files. The facilities include parameter passing; labels; loops; I/O, file-handling, and error-handling facilities; and a menu driver that lets you set up interactive menu-driven user interfaces. $395.

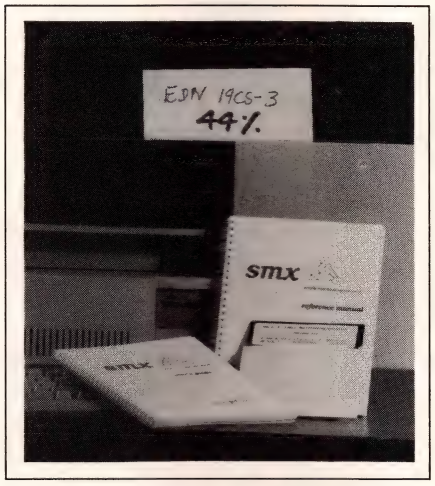
Gespac Inc, 50 W Hoover Ave, Mesa, AZ 85210. Phone (602) 962-5559. FAX 602-962-5750.

Circle No 382

MULTITASKING TUTOR

- *Provides a subset of a real-time executive*
- *Teaches you how to develop small applications quickly*

A reduced version of *smx* (simple multitasking task), *smx* CK (college kit), includes all the important calls and features of the full version. The subset operates at full speed and is ROMable. The package includes



a "protosystem" to which you can add your own code, *make* files, a tips file containing helpful hints and guidelines, a program that lets you time *smx* operations, and other useful utilities. The User's Guide is tutorial in nature and encourages you to develop a multitasking application as you read, using the protosystem as the foundation. The package also includes a complete reference manual. *smx* CK runs on systems based on μPs of the Intel 80X86 family and works with Microsoft's and Borland's C compilers and assemblers. $95.

Micro Digital Inc, 6402 Tulagi St, Cypress, CA 90630. Phone (714) 891-2363.

Circle No 383

ASIC DESIGN TOOL

- *Automatically generates balanced clock tree*
- *Provides back-annotation by geometric layer comparisons*

Avant Gards 2.0 runs on DEC, Sun, and Apollo workstations and lets you design channel-less, sea-of-gates logic arrays containing as many as 250,000 gates. You can specify net thresholds and weights for all nets in your design; this information is used by the placement and routing modules to ensure first-pass, timing-correct layouts. The placement module automatically generates a balanced, distributed clock tree; the algorithms consider area and buffer placement by partitioning the chip into "bins" and synthesizing the clock tree according to maximum buffer fan-out. Thus, all clocked elements receive synchronized clock inputs. Buffers inserted by the program to equalize delays are back-annotated into the net list. The rip-up-and-reroute algorithms don't permit design-rule violations or shorts and, as a result, ensure 100% completion in minimal CPU time. The engineering-change-order facilities accept netlist changes without requiring complete placement and routing reiteration. The back-annotation algorithms are optimized for speed and can reduce the time for a back-annotation report to as little as one-fifth the time required by previous versions. $225,000.

Silvar-Lisco Corp, 1080 Marsh Rd, Menlo Park, CA 94025. Phone (415) 324-0700. FAX 415-327-0142.

Circle No 384

DOS EXTENDER

- *Lets you address as many as 16M bytes of memory on an 80286*
- *Lets real-mode applications address 900k bytes on an 80386*

OS/286 and OS/386 DOS extenders facilitate the development of application programs that can address as many as 16M bytes of memory in protected mode on an 80286, or as many as 4G bytes on an 80386. You can also run 80386-based applications in multitasking systems. Both extenders now adhere to the virtual control program interface specifications that allow them to run under DESQview 386 to provide multitasking capabilities. The kernel now occupies only 40k bytes of the 640k-byte address space, so it can run in real mode with other

large resident programs. OS/386 has a Virtual-8086 mode that allows real-mode applications to address as much as 900k bytes of memory. Real procedure calls allow selected portions of an application to run in real mode while the remainder of the application runs in protected mode. Both OS/286 and OS/386 come with two utilities: Tune and .EXPress. Tune is a setup program that automatically configures the extender for optimum performance on your specific system. The EXPress utility permits direct, 1-step conversion of a real-mode executable file to protected-mode, thereby simplifying debugging and removing the 640k-byte limit of real mode. Developer's Kit, which includes the full suite of development tools, $495.

A I Architects Inc, 1 Intercontinental Way, Peabody, MA 01960. Phone (508) 535-7510. FAX 508-535-7512.

Circle No 385

POSTSCRIPT ON FAX

- *Lets you send fax images composed with PostScript*
- *Also handles HP-GL and AutoCAD plotter files*

GammaScript converts images that you've produced with application programs that support PostScript into a form that you can send directly to a fax machine. Because you don't need to scan hard copy of the image, the received fax looks exactly as if it were printed on a 200-dpi PostScript printer. In addition to converting PostScript files, the program can also convert HP-GL and AutoCAD plotter-language files for fax transmission. To run the program you need an IBM PC/AT, PS/2 Model 50, or compatible, that has at least 1M byte of RAM, 4M bytes of free disk space, and a GammaFax PC-to-fax board. Two versions are available: GammaScript Starter gives you 13 fonts compatible with the original Apple

LaserWriter; GammaScript gives you 35 fonts compatible with the Apple LaserWriter NT. If you order the Starter version, you can later obtain the other 22 fonts in an upgrade package. GammaScript Starter, $145; GammaScript, $440; upgrade package, $295.

GammaLink, 2452 Embarcadero Way, Palo Alto, CA 94303. Phone (415) 856-7421. FAX 415-494-7042.

Circle No 386

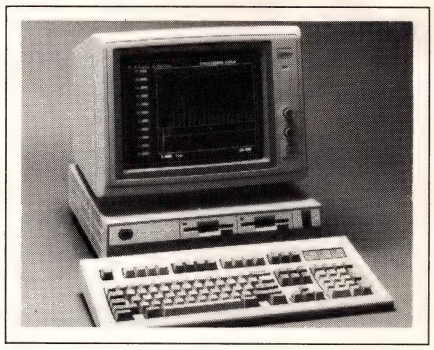
C++ TOOL SET

- *Lets you create object-oriented programs written in C++*
- *Runs on Sun workstations; other versions are in preparation*

Objectworks for C++ is a set of software-development tools that lets you create and manage object-oriented system and application programs written in C++. Objectworks for C++ runs on Sun-3 workstations under SunOS 3.2 or higher. The package includes AT&T's C++ Language System, release 2.0. You create your programs using a mouse-oriented editor, which provides syntax-error-message annotation and an on-line query and help facility. Alternatively, you can use any full-screen editor such as *vi* or EMACS. The incremental compiler/linker module first calls up the C++ translator, which generates standard C code, and then calls the host's standard C compiler. Finally, it links the new or modified functions. For debugging, you use the interactive, source-level, symbolic debugger. The source-code browser lets you view the class hierarchy and file structure of application code; you can search for implementors or callers of a function, or references to data types. The category browser provides an abstract level of program organization. The change-management tools help you keep track of source-code updates and provide change-rollback and infinite undo facilities. To run Objectworks for C++, your Sun-3 must have at least 8M bytes of RAM and 20M bytes of free disk space. $2495.

ParcPlace Systems, 1550 Plymouth St, Mountain View, CA 94043. Phone (415) 691-6700. FAX 415-691-6715.

Circle No 387



MULTI-μP SIMULATOR

- *Lets you simulate as many as seven μPs simultaneously*
- *Lets you mix digital and analog functions*

Tutsim Professional is a block simulation language that has been upgraded to let you implement as many as seven μPs in a single simulation. You can mix analog and digital functions and can implement digital filters, z-transforms, correlation, and many other engineering algorithms. Professional version, $595; evaluation version with manual, $40.

Tutsim Products, 200 California Ave, #212, Palo Alto, CA 94306. Phone (415) 325-4800. FAX 415-325-4801.

Circle No 388

Our low-cost OS/2 tools put more muscle in your PCB design.

Tired of paying up to $80,000 per PCB design seat? Look at LEDAX™ Plus. For $8,795, you can put our complete workstation-proven, workstation-powerful toolset on every OS/2™-Presentation Manager PC platform.

LEDAX Plus is tightly coupled and highly interactive, with fast, easy control from schematic capture step-by-step through design to photo-tooling. Advanced functionality and networking with complete Sun/Apollo/VAX compatibility. True multi-tasking. "Point and click" mouse/icon-based graphical interface. Virtual memory with no MS-DOS constraints. Result: reduced design time, improved manufacturability and reliability.

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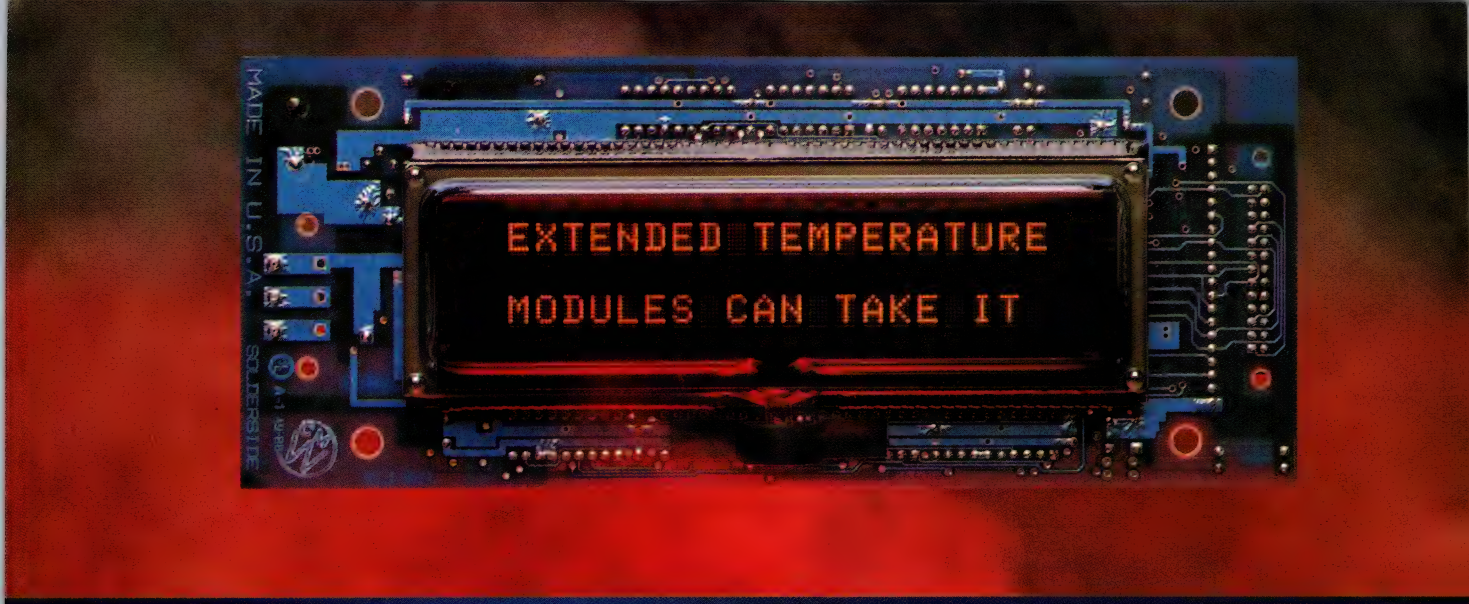
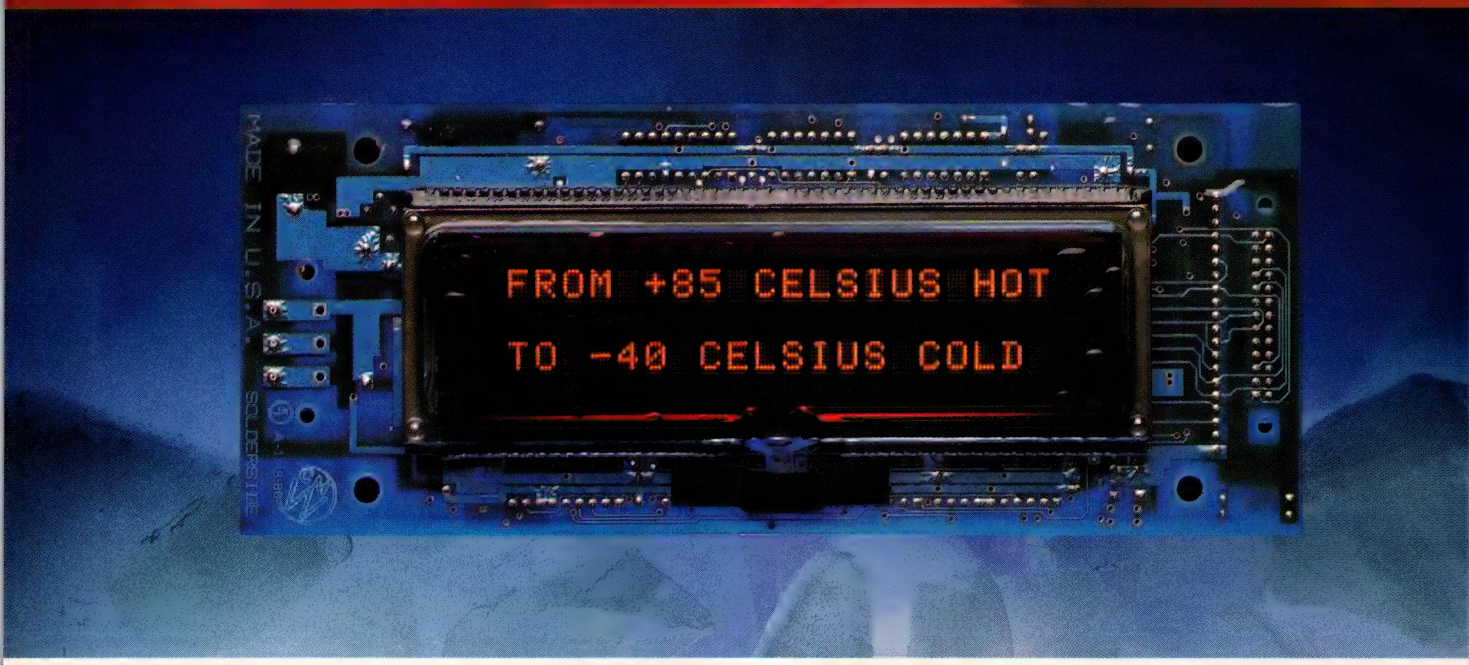
CIRCLE NO 125





THE VF MODULES TO USE IF HELL FREEZES OVER.

If that day arrives and you need a clear readout, DeeCO's XT and XTB extended temperature display modules won't let you down.

From −40°C to +85°C, through 40g shock and 2g rms vibration, XT series modules can take the heat. And the cold. And whatever else you or the forces of evil throw at them.

And when you need clear sunlight readability, our XTB1x40 high brightness extended temperature module delivers more than 600 fl of brilliant performance.

XT and XTB features include selectable baud rates, 15 microsecond-per-character burst mode for high-speed display changes, steady or flashing characters, and brightness control.

If you'd like further proof of how well we go to extremes, we'd be happy to send you test results from an independent testing lab. For more information about XT and XTB extended modules, or our full line of VF and EL display products, write or call (415) 471-4700.

deeco®

Digital Electronics Corporation, 31047 Genstar Road, Hayward, CA 94544-7831 (415) 471-4700. DeeCO is a registered trademark of Digital Electronics Corporation © 1989.

CIRCLE NO 126

NEW PRODUCTS

TEST & MEASUREMENT INSTRUMENTS

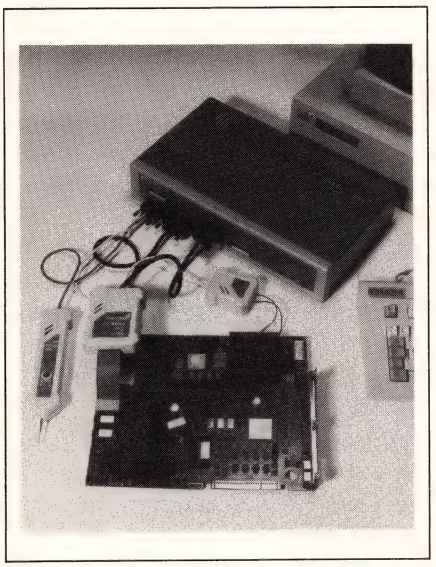
LOGIC ANALYZERS

- *Can monitor 192 channels at 100 MHz or 72 channels at 1 GHz*
- *Controlling software runs under MS Windows*

The logic analyzers in the PL1000 line incorporate three slots that let you configure them to monitor simultaneously as many as 144 channels at 500 MHz (72 channels at 1 GHz) or 192 channels, synchronous or asynchronous, at 100 MHz (96 channels at 200 MHz). You can intermix modules to create, for example, a unit with 48 500-MHz channels and 64 100-MHz channels with cross-triggering and time alignment. Or you can include a 64-channel, 50-MHz pattern generator with 1k or 4k bits of pattern memory per channel. The PL1000 connects to your IBM PC/AT-compatible computer via a proprietary high-speed parallel interface; the PL1000+, which incorporates such a computer and interface, acts as a portable high-performance logic analyzer. The menu-driven controlling software runs under MS Windows. The vendor offers an extensive set of 8-, 16-, and 32-bit disassemblers. From $6195.

Kontron Electronics Inc, 630 Clyde Ave, Mountain View, CA 94039. Phone (800) 227-8834; in CA, (415) 965-7020. FAX 415-965-3505. TWX 910-965-7020.

Circle No 375



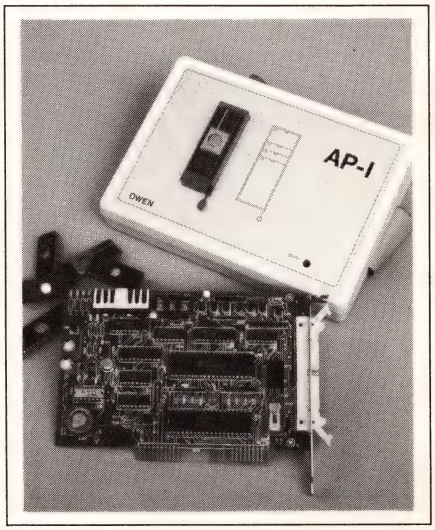
8/16/32-BIT EMULATOR

- *Allows waveform analysis to 100 MHz*
- *Permits real-time emulation without wait states*

The MT2000 digital test system is a PC-hosted, emulation-based tester for 8-, 16-, and 32-bit μPs. It performs waveform analysis to 100 MHz and, in many cases, permits real-time emulation with no wait states. Because the emulator is software configurable and is based on ROM-emulation techniques, it adapts to a wide variety of processors with software changes only—no hardware modifications or adapters are needed. The vendor claims that this design approach will also permit the tester to work without hardware modification with future μPs. Libraries of preprogrammed diagnostics and lower level procedures accompany the unit. The two types of software permit you to use the tester with a minimum of programming or to design your own customized programs for it. From £5400.

Electrotest, Unit 4, Industrial Estate, Falcarragh, County Donegal, Ireland. Phone (074) 35444. FAX 074-35468.

Circle No 376



PROGRAMMERS

- *Universal unit has D/A drivers on 40 of 48 pins*
- *Both units use proprietary IBM PC-bus interface*

The AP-I EPROM/EEPROM programmer handles 8-bit-wide devices, from the 2716 (16k bytes) to the 27010 (128k bytes), and the 40-

pin, 16-bit-wide 27210 (64k words). It can also program devices with a 32-bit-wide data path. The AP-II is a universal PLD/PROM programmer that handles devices with as many as 48 pins. The AP-II has pin drivers that incorporate 8-bit D/A converters with 25.5V maximum output on 40 pins. It can read from and write to every device pin. Both units require an IBM PC-compatible computer. Each programmer includes a proprietary interface card that plugs into the PC bus. AP-I, DM 898; AP-II, DM 3548.

Owen Electronic GmbH, Ringstrasse 11, Postfach 1104, D-6798 Kusel, West Germany. Phone (06381) 5085. FAX 06381-8584.

Circle No 377

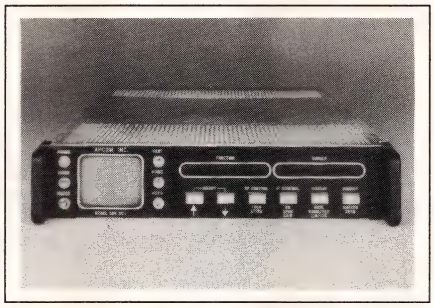
286/386 DIAGNOSTICS

- *Test all major subsystems of 80286- and 80386-based PCs*
- *Provide English-language diagnostic messages*

Amidiag is a diagnostic software package for PCs based on the 80286 and 80386 μPs. The software tests the following computer subsystems: mother board, memory, hard-disk drives, floppy-disk drives, keyboard, video adapter, monitor, serial port, and parallel printer port. Diagnostic messages are presented in English rather than in cryptic codes. You can configure the software to suit the hardware setup and operate it in interactive, continuous, time-bound batch, or count-bound batch modes. Graphic displays indicate the location of defective DIP switches and single in-line memory modules. The hard-disk tests work on controllers that use MFM (modified frequency modulation) encoding and conform to the ESDI (enhanced small-disk interface) standard. $99; board-based diagnostic module, $995.

American Megatrends Inc, 1346 Oakbrook Dr, Suite 120, Norcross, GA 30093. Phone (404) 263-8181.

Circle No 378



SPECTRUM DISPLAY

- *Two units fit side by side in 1¾-in. rack space*
- *Can have four center frequencies and sweep widths*

The 500SDU is a small spectrum-display unit. Two of the instruments fit side by side in a 1¾-in.-high rack space. You can order the units with a variety of capabilities. Each unit can have four center frequencies; all units have a 160-MHz center frequency. Other common frequencies are 21.4, 70, and 250 MHz. Commonly chosen sweep widths are 1, 5, 10, 20, and 40 MHz. Other options include linear and logarithmic amplitude displays, forward and reverse sweeps, and automatic zeroing. Front-panel pushbuttons select operating modes, and the CRT presents an alphanumeric display of the selection. From $6000.

Apcom Inc, 8-4 Metropolitan Ct, Gaithersburg, MD 20878. Phone (301) 948-5900. FAX 301-948-1631.

Circle No 379

RESPONSE ANALYZER

- *Measures gain, phase, and harmonics from 0.01 Hz to 10 kHz*
- *Uses correlation techniques to perform Fourier analysis*

The TF2000 frequency-response analyzer measures gain, phase, and harmonics from 0.01 Hz to 10 kHz in electrical and mechanical systems. You can use it to generate a Bode plot in less than 10 minutes from the initial setup. The instrument, which is completely contained within a 10×9.75×4-in. enclosure, weighs 6.6 lb and includes a programmable swept-sine-wave generator. The two input channels are isolated from the chassis and withstand common-mode voltages as high as 500V. Correlation-based Fourier analysis measures harmonics as high as the 39th. The unit can display its results on the front panel or can drive both RS-232C and Centronics parallel-interfaced printers. $4950.

Voltech Inc, 200 Butterfield Dr, Ashland, MA 01721. Phone (508) 881-7329. FAX 508-879-8669.

Circle No 380

TEST SOFTWARE

- *Develops programs for VXI and IEEE-488 instruments*
- *Requires no programming knowledge*

TekTMS software is a control-program generator for instruments with IEEE-488, RS-232C, and VXIbus (VME extensions for instrumentation) interfaces. You need no knowledge of programming to use it. The software runs under MS Windows on IBM PC/AT-compatible computers. The main portions of the package are an interactive program generator and the instrument libraries. An instrument script language allows you to add instruments to the libraries. The software displays one or more interactive front panels in windows on the computer's screen. You control the setups from the keyboard or a mouse using icons, such as slide switches. You can view the control program in a scrollable window and edit it via pop-up dialog boxes. To aid operators in placing probes on units under test, the programs created by the software can display bit-mapped pc-board layouts created with several drafting programs. $2995 with an IEEE-488 or VXI library.

Tektronix Inc, Box 1700, Beaverton, OR 97075. Phone (800) 835-9433, ext 170.

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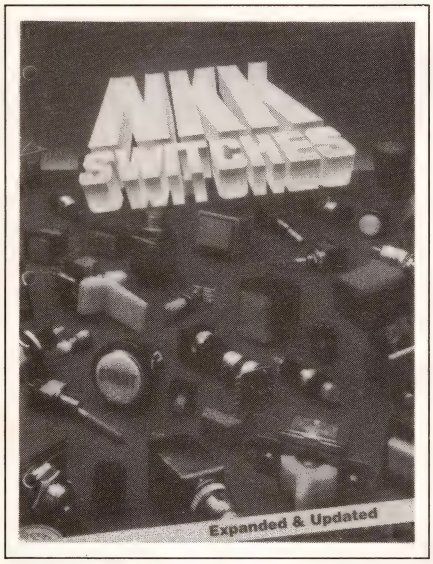


Expanded publication of switches

This catalog is a comprehensive compendium of electromechanical switches. The 400-pg book features 36 separate switch families and more than 827,000 different toggle, rocker, pushbutton, slide, keypad, illuminated, rotary, and dip-rotary switches. The dimensional drawings ease the design-in process.

NKK Switches, 14415 N Scottsdale Rd, Scottsdale, AZ 85260.

Circle No 389

Comprehensive coverage of application-specific ICs

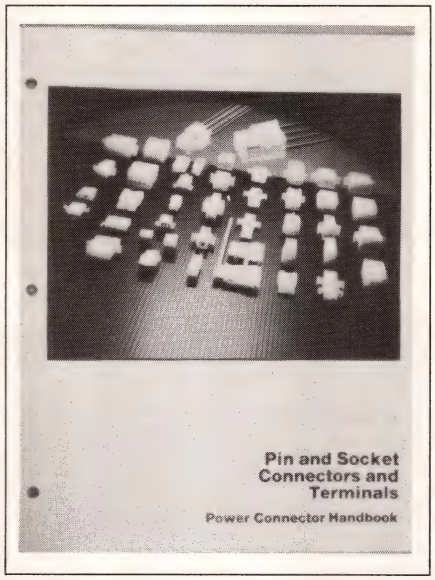
Providing a forecast for the 1990s and serving as a directory of ASIC vendors, *ASIC Outlook 1990, An Application Specific IC Report and Directory*, contains seven sections. Section 1 outlines various ASIC solutions and defines basic ASIC segments. Section 2 presents an analysis and forecast of the global semiconductor industry to 1993, and Section 3 makes a worldwide survey of major IC producers. In Section 4, the worldwide ASIC market is analyzed, Section 5 discusses cost effectiveness, and Section 6 deals with technology trends. Section 7, comprising the ASIC vendor directory, provides an alphabetical listing of more than 100 ASIC vendors. $485.

Integrated Circuit Engineering Corp, 15022 N 75th St, Scottsdale, AZ 85260.

INQUIRE DIRECT

Handbook guides choice of power connectors

A 24-pg handbook on pin and socket connectors helps you choose the best power connector for your needs. The booklet covers specifications such as current rating, connector size, engagement force, configuration and circuit size, and operating voltage.

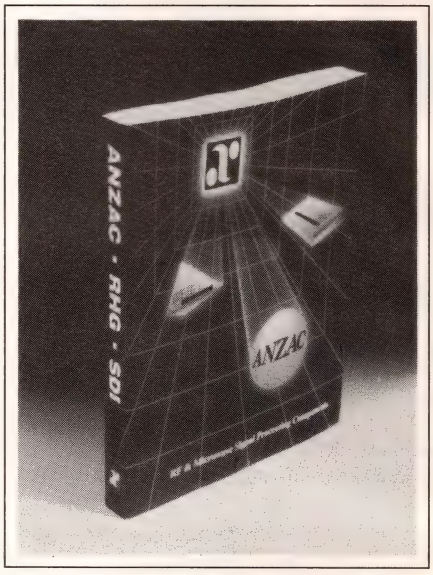


Molex Inc, 2222 Wellington Ct, Lisle, IL 60532.

Circle No 390

Compilation of RF and microwave components

This catalog categorizes more than 500 RF and microwave components. It depicts more than 150 products, including GaAs monolithic microwave ICs, logarithmic amplifiers, RF and microwave control devices, mixers, and hermetic surface-mount devices. Application notes and selection guides complete the catalog.



Adams-Russell Electronics Co Inc, 80 Cambridge St, Burlington, MA 01803.

Circle No 391

Extensive catalog presents IEEE-488 products

The vendor's 1989 spring/summer catalog offers an extensive product line of IEEE-488 instrument-control, data-acquisition, and data-analysis products. The 300-pg publication is divided into four sections: application software, GPIB interfaces, data acquisition, and the VXIbus. Recent product additions include updated versions of LabView, LabWindows, and Measure application-software systems; an IEEE-488 data buffer; and a series of IEEE-488 interface kits for Sun, Apollo, DEC, and IBM workstations. The catalog also provides tutorial sections.

National Instruments, 12109 Technology Blvd, Austin, TX 78727.

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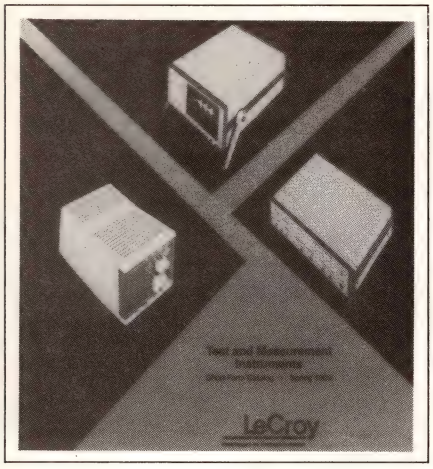
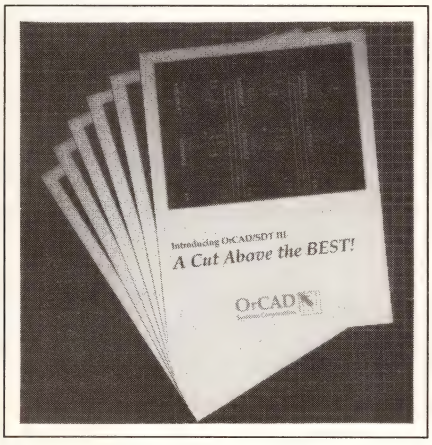


Concise listing of test and measurement products

This short-form catalog of test and measurement instruments represents the vendor's first condensed catalog of products. It provides descriptions of signal sources, digital oscilloscopes, and high-speed waveform digitizers.

LeCroy, 700 Chestnut Ridge Rd, Chestnut Ridge, NY 10977.

Circle No 393



Brochure and disk teach complex schematic design

This 4-pg brochure and accompanying demonstration disk present software for designing complex schematics on a PC. The document describes OrCAD/SDT III's features, such as pop-up menus, design management, and powerful utility programs. The brochure provides clearly reproduced screens of the software's primary design tasks and lists 25 features; the disk guides you through the basics of the schematic-capture software.

OrCAD Systems Corp, 1049 SW Baseline St, Suite 500, Hillsboro, OR 97123.

Circle No 394

Integrated approach to robotics

A 336-pg hardcover book, entitled *Industrial Robotics, Machine Vision, and Artificial Intelligence,* emphasizes how the integration of machine vision and AI with a flexible automation/manufacturing system can enhance manufacturing in the future. Some of the topics covered include components of robot systems, machine vision systems, analysis of 2-D images, 3-D machine vision, sensors for robot-based assembly, AI basics, AI in manufacturing, and AI/expert systems scheduling in manufacturing. $39.95.

Howard W Sams & Co, 4300 W 62nd St, Indianapolis, IN 46268.

INQUIRE DIRECT

App note discusses use of thermistors

Application note No. 2, *Selecting and Using Thermistors for Temperature Control,* describes the characteristics of thermistors, thermistor families, and calibration. The publication concludes with a summary of thermistor selection. Four figures illustrate the text.

ILX Lightwave Corp, Box 6310, Bozeman, MT 59771.

Circle No 395

How to condition thermocouple signals

The company's application note, *AN-28: Thermocouple Measurements,* opens with a brief history of thermocouples and a table showing the relative precision and accuracy of common thermocouple types. The main thrust of the note is on electronically conditioning thermocouple signals to improve the accuracy of their temperature measurements. It includes a discussion of cold-junction compensation, signal-amplifier selection, isolation, and linearization. Also included are schematics for electronic cold-junction compensators.

Linear Technology Corp, 1630 McCarthy Blvd, Milpitas, CA 95035.

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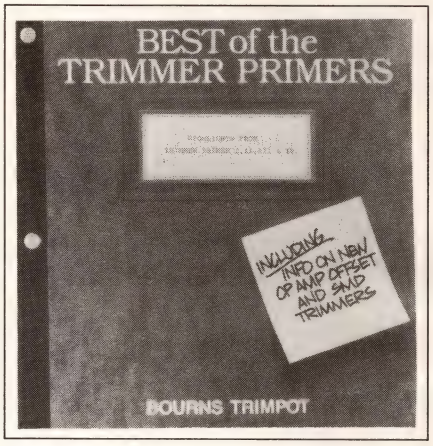

Anthology of trimmers

Best of the Trimmer Primers is a condensed version of the 4-volume Trimmer Primer series. The booklet contains information about application-specific trimmers and SMT products, as well as solutions to common trimmer problems. Section 1 deals with the basics of trimming potentiometers. The fine tuning of circuits with variable resistors and center-tap trimmers is the subject of Section 2. The third section presents an advanced course on the voltage divider and rheostat modes, linearity, adjustability and resolution, and end-zone characteristics. Section 4 focuses on soldering, board washing, seals, mechanical menaces, and operating environments. The final section delves into SMD technology.

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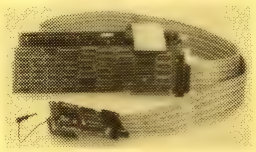

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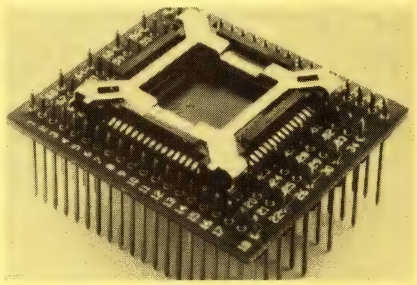

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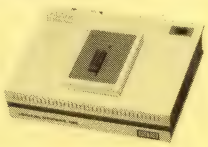

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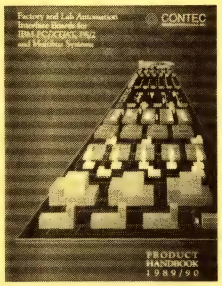

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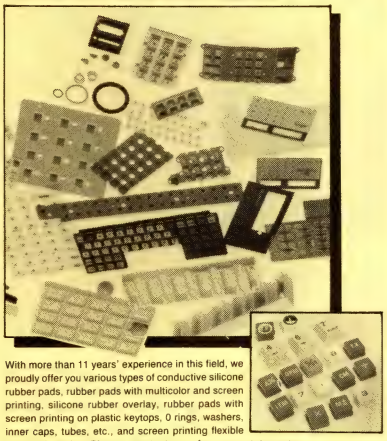

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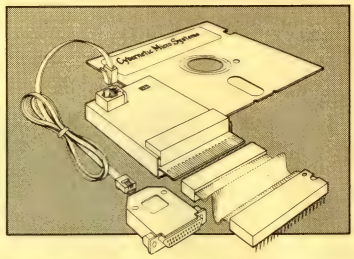

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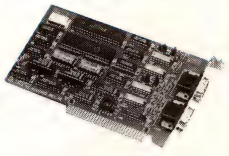

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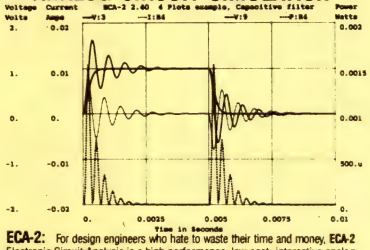

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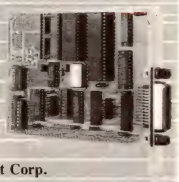

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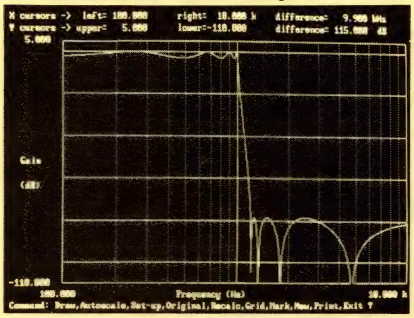

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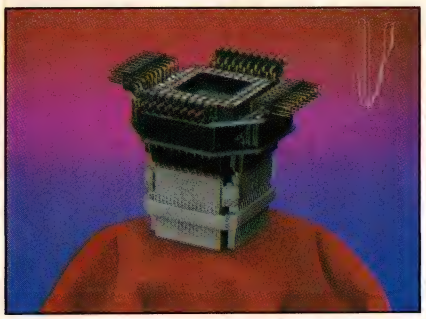

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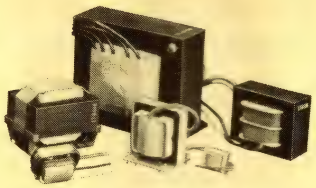

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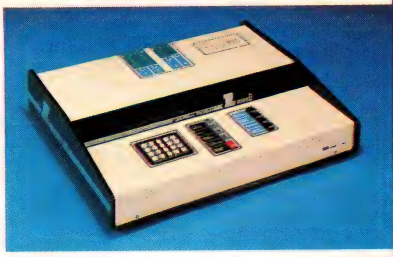

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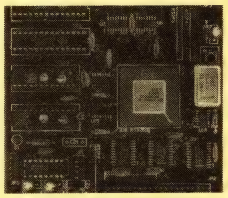

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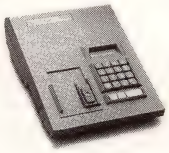

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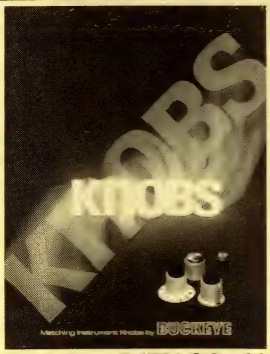

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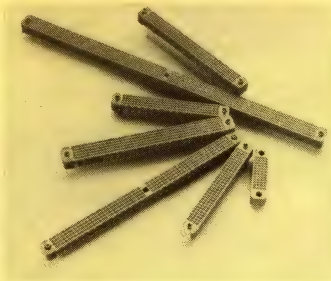

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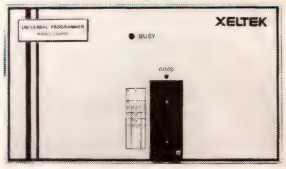

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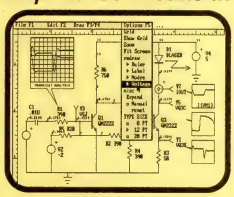

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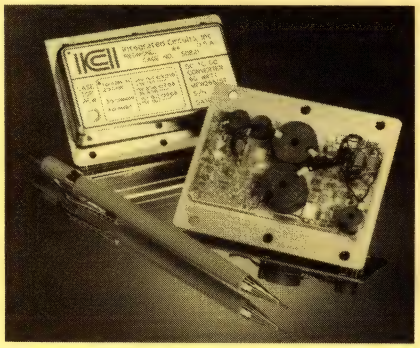

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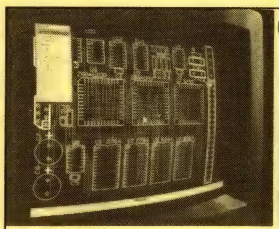

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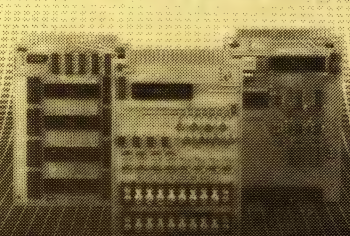

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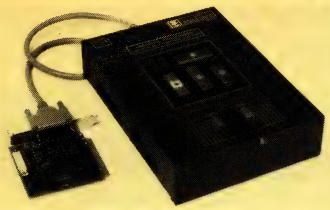

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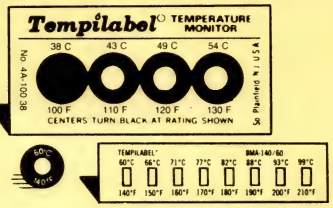

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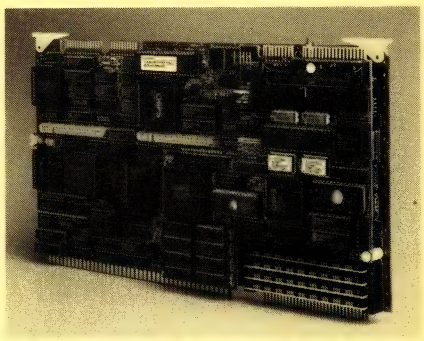

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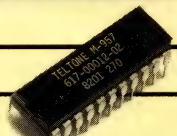

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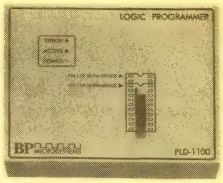

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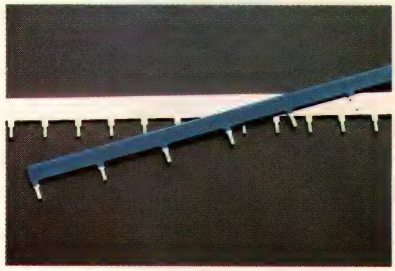

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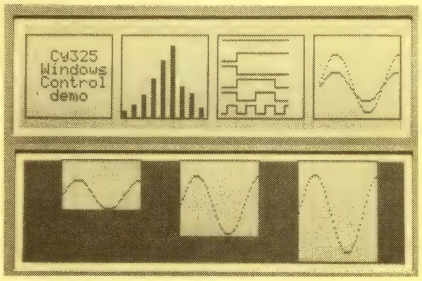

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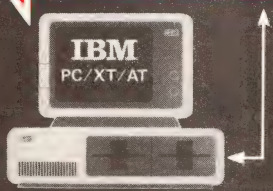

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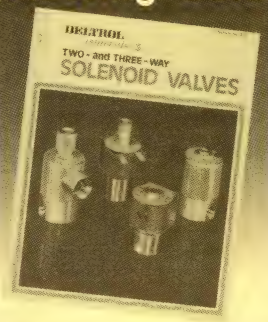

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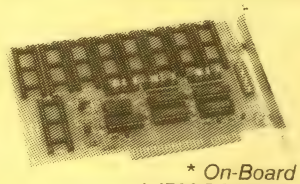

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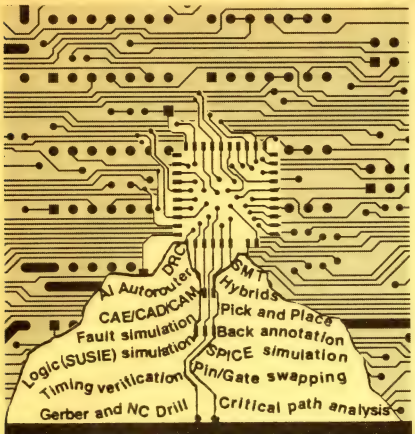

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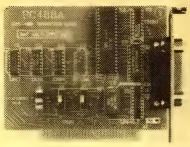

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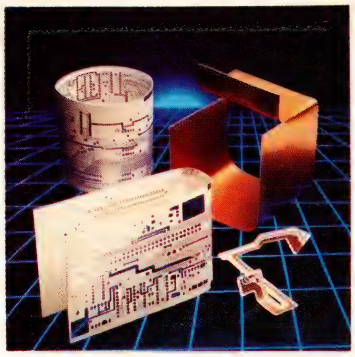

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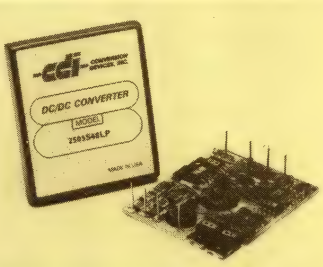

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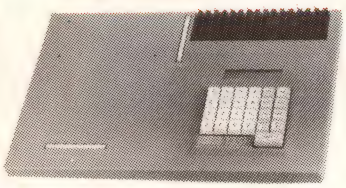

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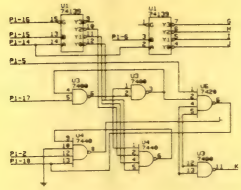

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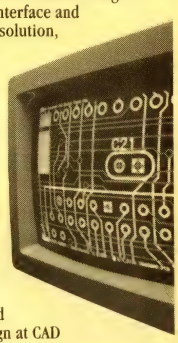

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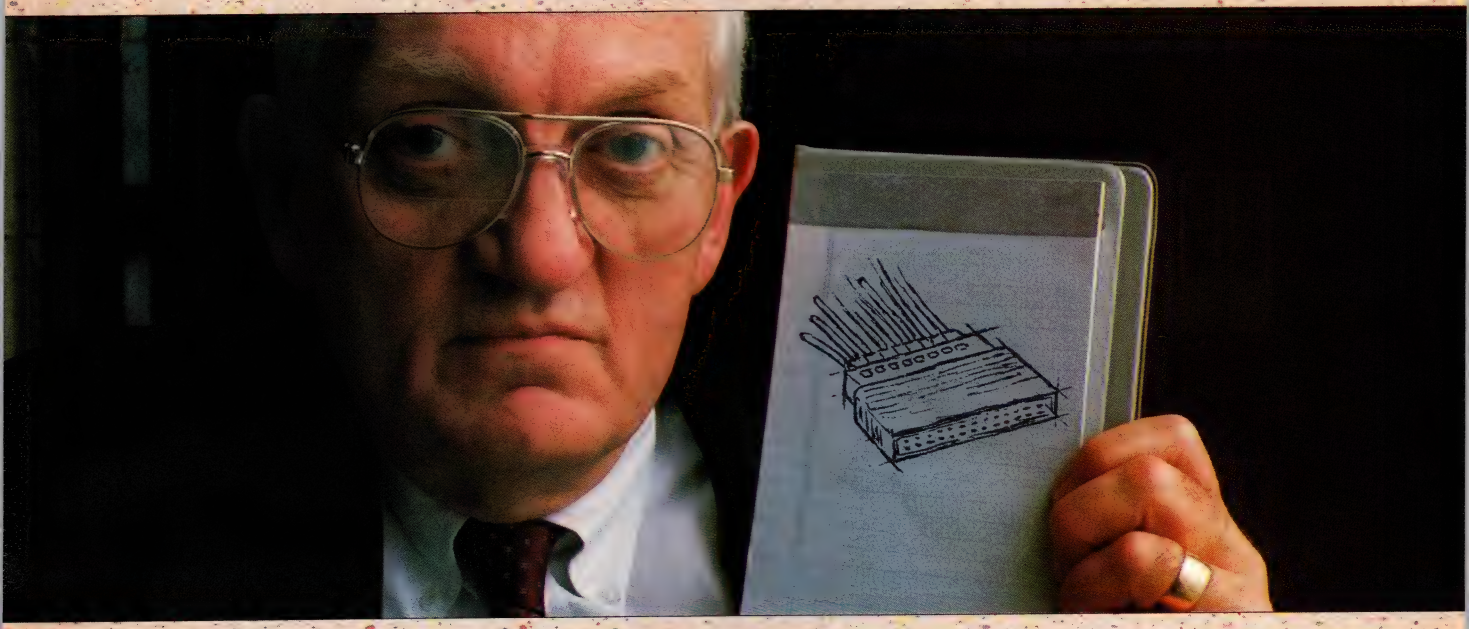

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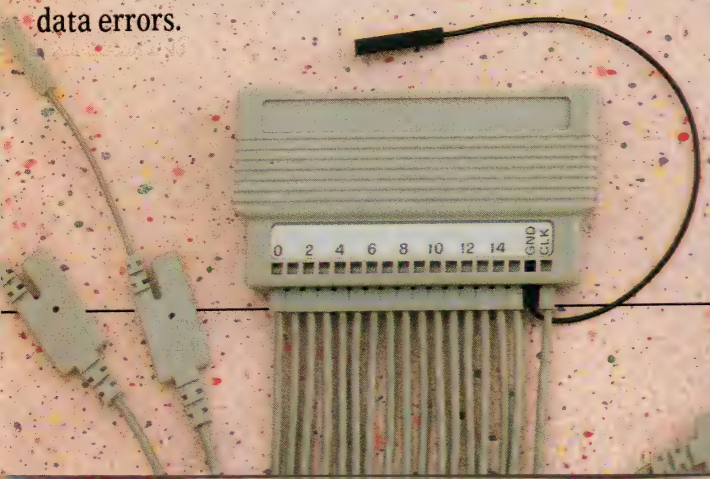

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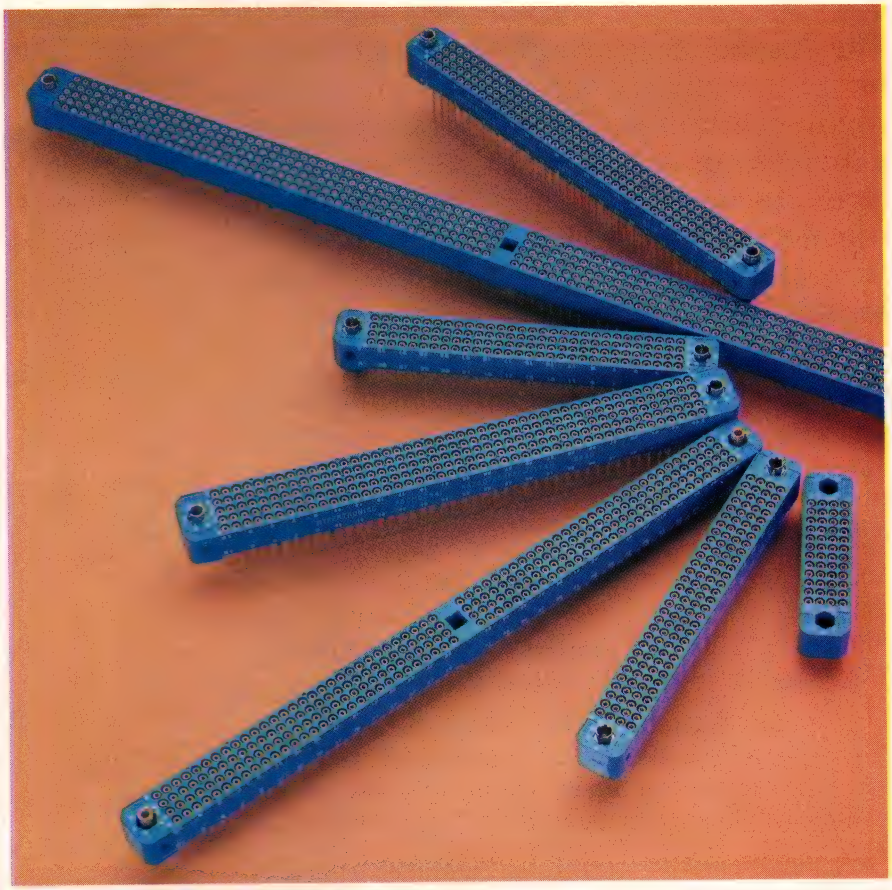

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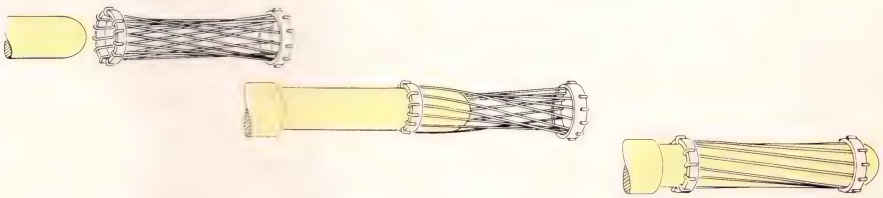

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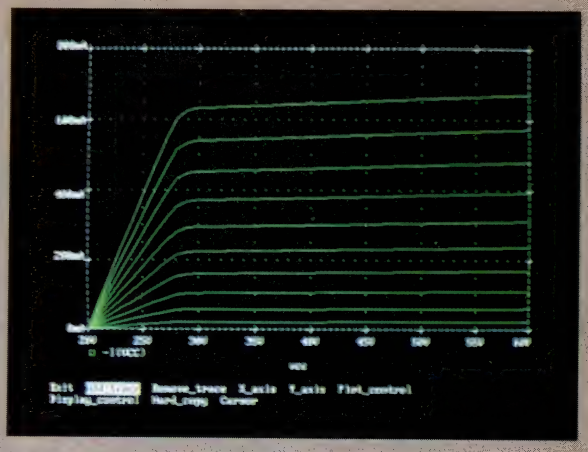

I-V curves of a triode vacuum tube

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The Analog Behavioral Modeling option for PSpice allows one to describe analog components, or entire circuit blocks, using a formula or a look-up table. For linear blocks, the description can be either a Laplace transform or a table of frequency response. Once defined, PSpice can simulate circuits including such blocks.

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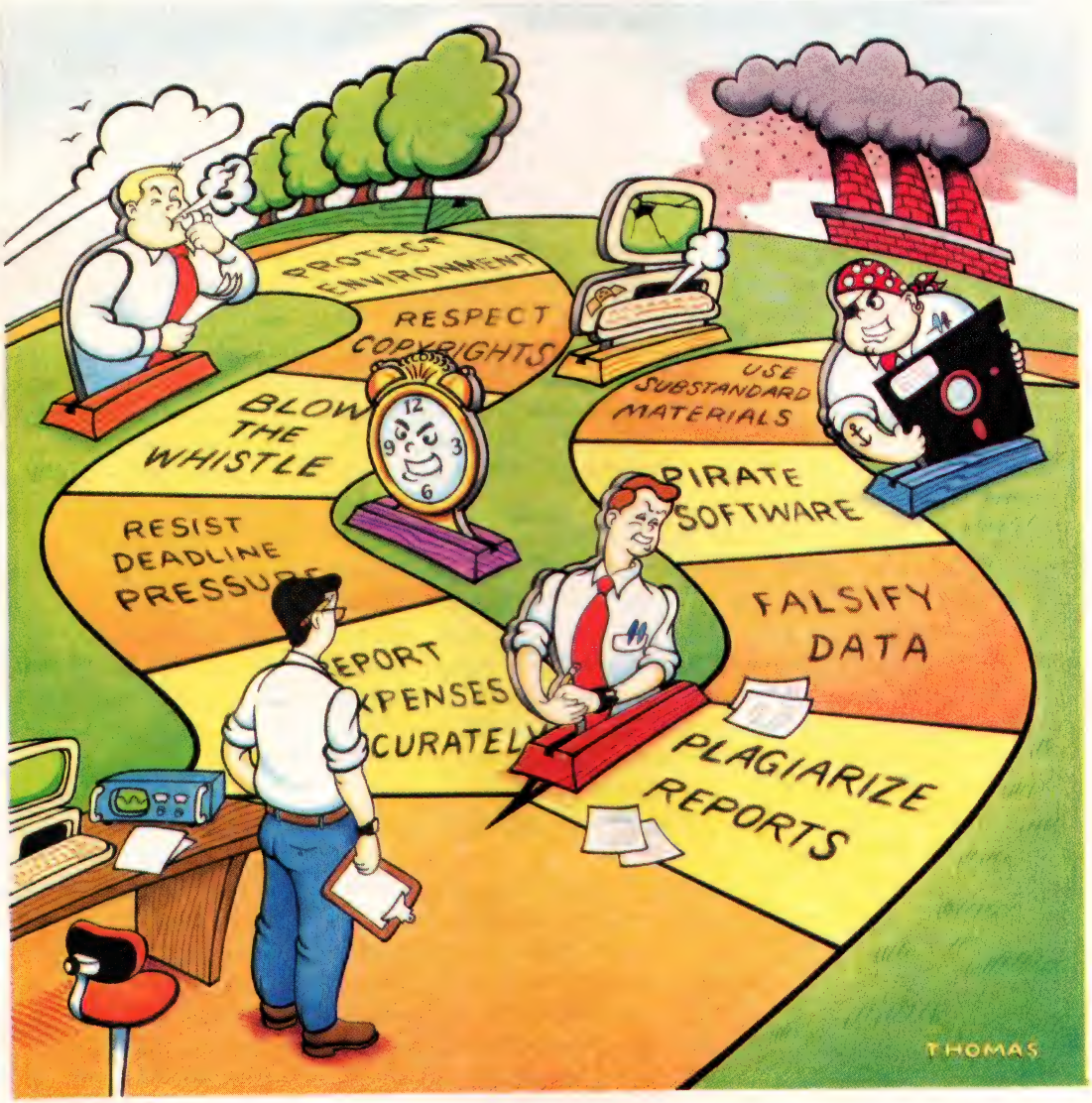
Business ethics
is not a contradiction in terms

Jay Fraser, *Associate Editor*



Rod Thomas

During the morning of November 3rd last year a virus struck Arpanet, the Defense Department's scientific-military computer network. At government installations, research laboratories, and universities across the country, people watched in horror as their computers began to run more and more slowly or stopped altogether. Many facilities had to shut down while specialists feverishly tried to halt the virus. Eventually it was eradicated and traced to Cornell University (Ithaca, NY). Allegedly, a 23-year-old graduate student there had unleashed it, disguised as a piece of electronic mail, not realizing how far and how fast it would spread.

The virus didn't destroy any data, but countless hours of research time were lost. Some facilities weren't up and running again for two or three days. A federal indictment has been issued in the case. Was this a prank that got out of hand or a serious breach of security? What the graduate student did may or may not have been illegal, but was it unethical?

Simply stated, ethics is the set of moral standards or rules that

govern the conduct of an individual or an organization. Most people carry in their minds some sort of personal code of ethics, although it may be vague. Some base theirs on their religious faith. Others base theirs on a secular philosophy or on a moral precept as simple as the Golden Rule. Some people just ask themselves the question: "Would I feel good explaining to my children what I'm about to do?"

Problems arise precisely because ethics is a personal matter. Two conscientious people can have an honest disagreement about what is and what isn't ethical behavior. In addition, not all ethical issues can be neatly divided into a choice between right and wrong. There is often a large gray area. Many people can't see clearly in gray areas and occasionally they lose their way.

Many experts see a decline in ethics in America today. In years past major scandals have dominated the headlines—Watergate, insider trading on Wall Street, money laundering by reputable banks, stock manipulation and fraud, and the Iran-Contra affair. What has gone wrong?

"We've done a terrible job of sensitizing our young people to ethical issues on the high school and college level," says Dr W Michael Hoffman, director of the Center for Business Ethics at Bentley College (Waltham, MA). "The teaching of ethics in high school is practically nonexistent. Business ethics wasn't even taught in college until about a decade ago. Our society is coming to realize that we have eclipsed the ethical dimensions of our lives."

Colleges and universities that teach computer science are not immune to this problem. Donn B Parker, a senior management systems consultant at Stanford University's (Stanford, CA) Research Institute International, writes in *Ethics and the Management of Computer Technology*, "In computer science departments I found some very thoughtful computer science professors who do impart ethical concerns to their students but many more who never even bother to think about the subject . . . Some faculty members said they don't deal with ethics, only with computers."

Trying to ignore ethical problems does not make them disappear, and the high-tech industry is certainly not free from them. In fact, the explosive development of modern technology has created a large number of new and unique problems, and they deserve special attention.

Every manufacturer has to guard against turning out products that don't meet specifications. Imagine a small software company locked in a struggle with its competitors. Imagine a project leader under pressure from above to put on the market as quickly as possible the program his team has been developing. Imagine that the project leader knows there are still a few bugs in the program, but they're minor. Ninety-five percent of the end-users will never come across them, and besides, they can be corrected in the first revision. The project leader may be sorely tempted to release the program as it is. Is it illegal to put a program on the market that you know contains some bugs? Probably not. Is it unethical?

A related problem can occur when a product is advertised. Most people would agree that it is unethical to knowingly run an advertisement that contains information that is factually wrong. But many advertisements aren't written to present cold, hard facts. They're written to persuade. Then the question becomes when is an advertisement trying to persuade and when does it step over the line and begin to mislead. A product that doesn't meet specifications is a concrete problem that can be dealt with. But what about a product that doesn't meet a customer's inflated expectations?

Is the use of proprietary protocols ethical? Some hardware manufacturers use standard protocols because they want their products to be used as widely as possible. Other companies have their own proprietary protocols. Is this to ensure that customers will use their products properly and get the maximum benefit out of them? Or do proprietary protocols unfairly limit customers' freedom of choice and force them to buy one company's products when they might prefer another's?

A series of ethical questions that has nagged the computer industry for years concerns development fees. For example, if a company commissions a software-development firm to create a program, should the development firm be free

to sell the same program to other customers? Or should the company that commissioned the program have exclusive rights to it? If one company pays for the time it takes to develop a program, and another company gets an off-the-shelf copy of it, should the second company be charged less? If the software firm charges both customers the same amount, is it overcharging the second customer?

This situation leads to one of the most troublesome ethical questions facing computer professionals—when is software protected and when is it unprotected?

Some computer programmers take out copyrights on the programs they create. However, copyrights may not always give programmers the protection they want. Deborah G Johnson, in her book *Computer Ethics* writes, "A company can copy a copyrighted program, change it just enough to raise difficult questions about improper appropriation, mass-produce it, sell it cheaply, and go out of business while the legal suit is hung up in the courts. This may not be illegal, but it certainly shows lack of respect for the property rights of others. In addition, we all know that it is sometimes possible and tempting to make illegal copies of programs without getting caught. This may seem harmless until, of course, it is your program that is copied."

If you have the source code of someone else's copyrighted program, what happens when you begin to modify it? How many changes do you have to make before it becomes a new program? And if you translate a program from one language to another, does it then become your own program? These problems are complicated even further because some programmers don't copyright their programs, but still claim proprietary rights. Is it unethical to use or copy or modify those programs?

These are some of the ethical problems that are unique to the high-tech industry. There are others that affect a much wider range of firms, but have been magnified by modern technology. A good example is the issue of personal privacy. The ability of electronic-information systems to store vast amounts of data and to transfer that data quickly has made the ethical questions surrounding privacy much more complex.

Almost all companies keep personnel files on their employees. Who decides what information goes into those files? And who is responsible if it is inaccurate? Even if the information is checked before it is entered, mistakes can still happen. Who is liable if someone's career is damaged because of a mistake? The person who entered the data? The company? Shouldn't the person who receives the information have a responsibility to recheck it?

Ethics will always remain the responsibility of the individual.

Most people would agree that firms have an obligation to keep their personnel files confidential, but that can be difficult if the data are stored in an information system. Access codes can be easily passed from person to person, and, as the graduate student from Cornell

proved, even tightly guarded systems are still vulnerable to break-ins.

"Every technical fix has a technical unfix," says Dr Mark J Pastin, director of the Lincoln Center for Ethics at Arizona State University (Tempe, AZ). 'Despite the fact that security companies would like you to believe they can keep your data safe, it's still largely a human system. You're relying on people's ethics to keep your system secure, and sometimes that just doesn't work.'

Obviously, the people who are entrusted with personnel files must be scrupulous about maintaining confidentiality, and companies should provide the best security possible, but that doesn't answer the question of who should have access to the files.

Should employees be allowed to see their own files? In 1966 Congress passed the Freedom of Information Act. Now any American citizen has the right to examine the files that any government agency has compiled on him. Should employees have the same right in a private company? Or should a private company be allowed to keep its files private?

Other ethical questions dealing with privacy that have been hotly debated recently center on mandatory drug testing. Is it an unwarranted violation of individual rights? Or is it a precautionary measure organizations can and should use to protect themselves?

The president of the United States has ordered drug testing for all federal employees, but there are a number of lawsuits currently making their way through the courts that would put a stop to it.

Should the government be allowed to demand a drug test from all its employees? Should a private company? A strong argument can be made that people who are responsible for the lives of others—airline pilots, for instance—should be tested for drugs. Should government employees who do work that involves issues of national security also be tested? What about high-tech companies that work on national security projects? Should their employees be required to take drug tests?

A few fortunate firms never have to lay workers off. Others, especially in fast-changing fields such as hardware manufacturing, may have to suffer through more than one layoff. The crucial decision that has to be made is who stays and who goes.

Should a company lay off its older employees and hold onto its younger ones? Or should it follow the old formula of last-hired, first-fired? Younger workers can contribute fresh ideas, new skills, and abundant energy, but don't older workers deserve some consideration for years of loyal service?

And who in the corporate hierarchy should have to bear the brunt of a layoff? Lower-level employees are often hit hardest. Is that unfair? Shouldn't the ranks of managers and executives have to absorb a proportional amount of any reduction in the work force?

Discussing these ethical issues has raised a great many questions but provided very few solid answers. Does this lack of answers mean that the realm of ethics is a huge morass where companies and their employees are doomed to flounder helplessly forever?

The explosive development of modern technology has created many new and unique ethical problems.

No, it does not.

Ethics will always remain ultimately the responsibility of the individual. Maintaining high moral standards isn't up to someone else. It's up to each person. However, companies do have a role to play. If a firm wants its employees to act ethically, it should promote and defend ethical standards. The following questions will help you judge the ethical climate within your company.

Does your company have a clear, written code of ethics? A code of ethics should be concrete and specific, and deal with everyday situations you might find yourself in. If your company doesn't have a code, one should be developed through discussions involving employees from all levels of the organization.

Does your company encourage open communication? Does your company have an ombudsman? An anonymous hotline? An independent watchdog committee? Firms should make sure that their employees' voices are heard.

Does your company punish unethical conduct? Does it reward people who uphold high moral standards? Punishments and rewards should be given out consistently and evenhandedly. Executives should be held just as responsible for their behavior as salaried employees.

Does your company review its own ethical conduct? A firm should examine itself periodically. It should consider how it treats its own employees, how it deals with its customers, and how it involves itself in the local community.

Companies that are lackadaisical about establishing and encouraging high ethical standards are running a grave risk.

"Unethical conduct can have enormous costs," says Hoffman. "It is often immediately followed by more government regulation, and that costs everyone, even the customer. It now costs business more than $100 billion every year just to comply with government regulations. Then there's the cost of a lost reputation. Some corporations spend millions to build up an image, and it can be shattered overnight."

A reputation for ethical integrity, on the other hand, can pay huge dividends. A firm known for its honesty will attract honest people to work for it. Morale among employees will be high, which means productivity will be high and absenteeism low. Turnover in the work force will be minimized. The company will avoid many legal problems and it will have good relations with the local community. Customers will trust its products and services and remain loyal to it, and investors will want to put their money into it. The rewards of maintaining high ethical standards can be summarized very simply—good ethics is good business. EDN

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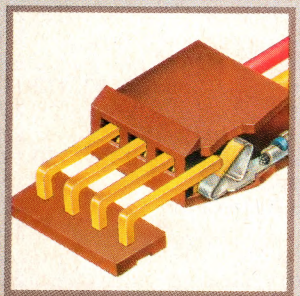

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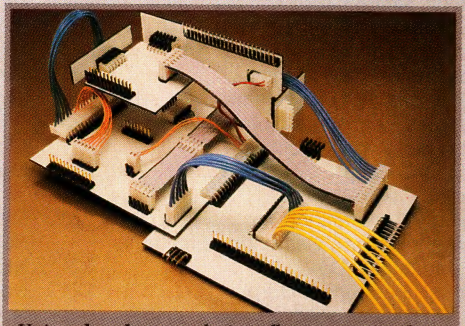

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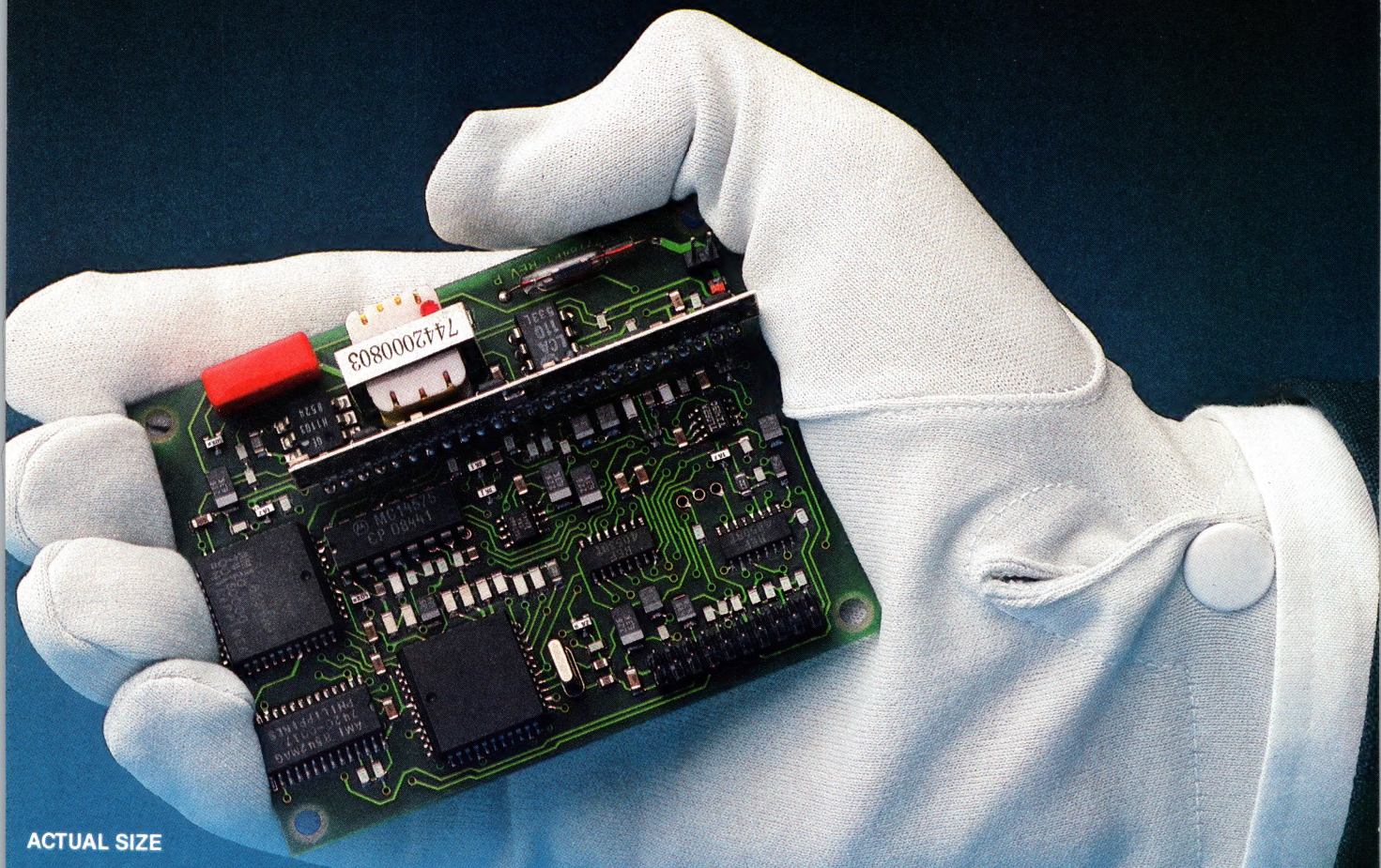

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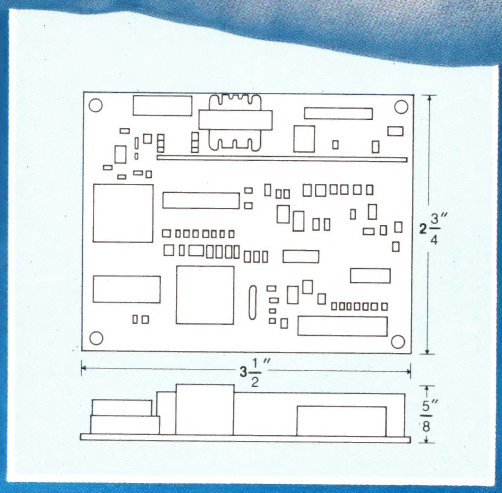

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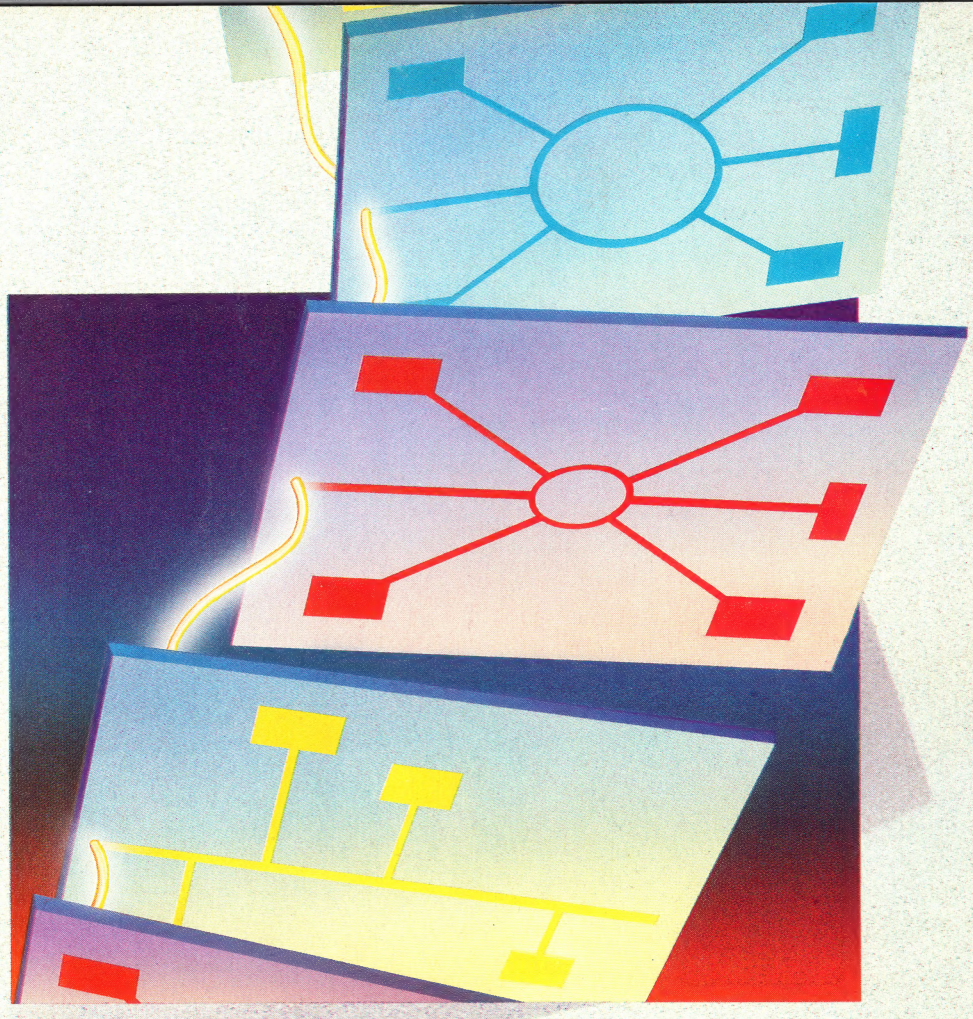

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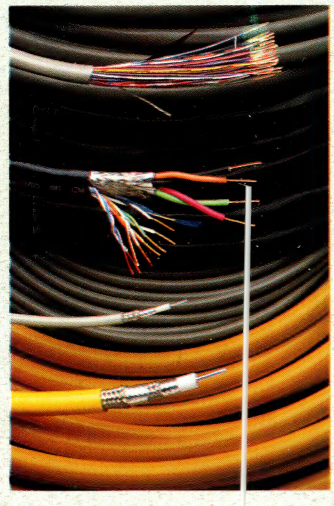

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